NCEP Radiative Transfer Model Status

Paul van Delst

Others involved

- John Derber, NCEP/EMC
- Yoshihiko Tahara, JMA/NCEP/EMC
- Joanna Joiner, GSFC/DAO
- Larry McMillin, NESDIS/ORA
- Tom Kleespies, NESDIS/ORA

NCEP (Community) Radiative Transfer Model (RTM)

- All components completed:
  - Forward, tangent-linear, adjoint, K-matrix.
  - Parallel testing of updated code in GDAS ongoing. Memory usage and timing are same (even with 2-3x more calculations) for effectively unoptimised code.
  - Code supplied to NASA DAO, NOAA ETL and FSL.
- Code availablility
  - Forward and K_matrix code available at http://airs2.ssec.wisc.edu/~paulv/#F90_RTM
  - Tangent-linear and adjoint code available soon.
- Code comments
  - ANSI standard Fortran90; no vendor extensions
  - Platform testbeds: Linux (PGI compilers), IBM SP/RS6000, SGI Origin, Sun SPARC.
  - Code prototyped in IDL. Not the best choice but allows for simple *in situ* visualisation and easy detection/rectification of floating point errors.

ADJOINT MODEL

OPTRAN absorber and predictor formulations

- Integrated absorber

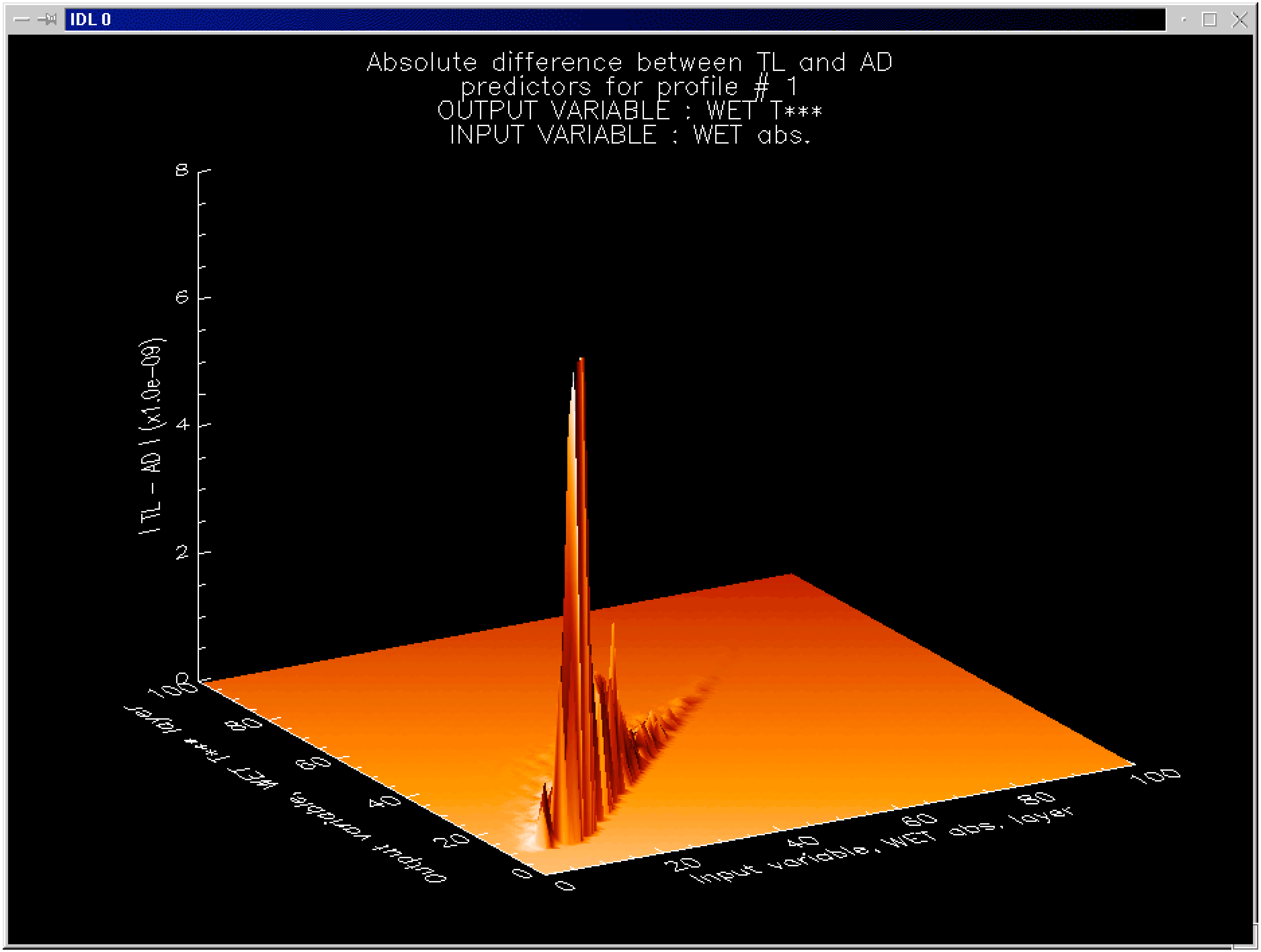
$$A(p) = \frac{\sec\theta}{g}\int_{p_0}^{p} q(p)\,dp$$

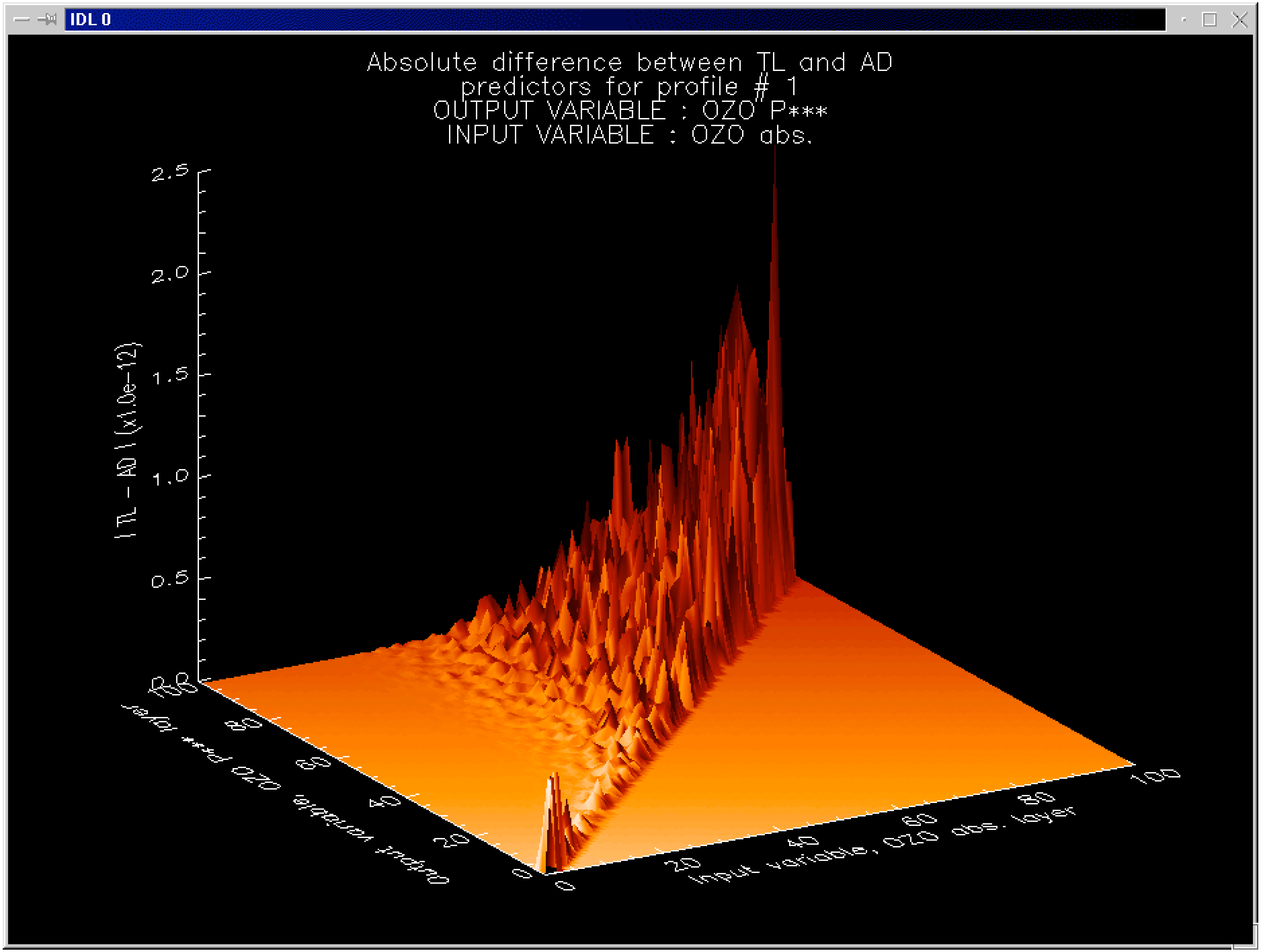
- Predictors
  - Standard; T, P, T^2, T.P, W, etc.
  - Integrated; X == T or P.

$$X^{n*}(A) = c\cdot\frac{\int_0^{A} X(A)A^{n-1}\,dA}{\int_0^{A} A^{n-1}\,dA};\quad n = 1, 2, \text{or } 3$$

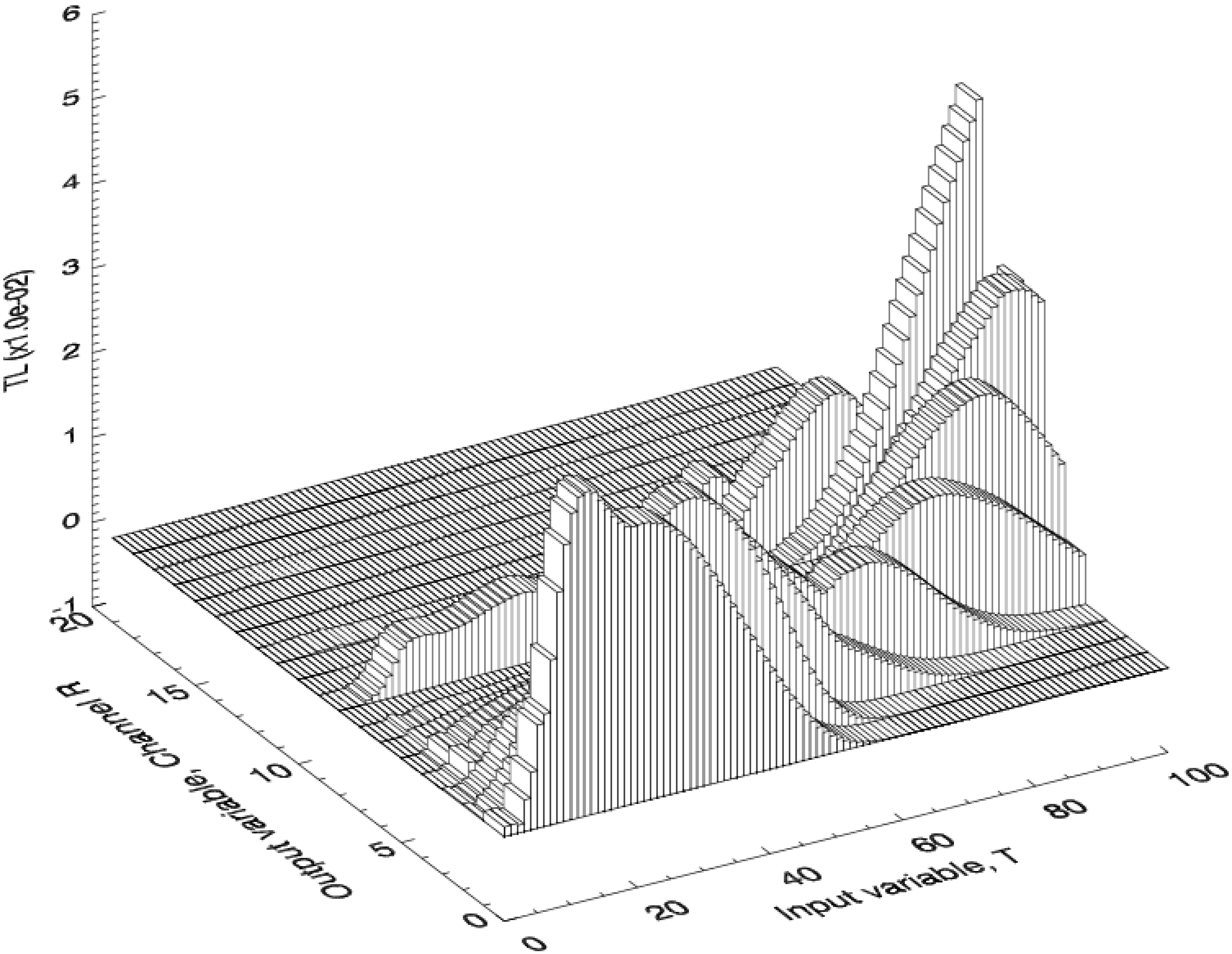
Adjoint model

- TL and AD models used in tandem for testing
  - If **H** == tangent-linear operator, then $\mathbf{H}^T = \mathbf{G}$ == adjoint operator.
  - For testing, $\mathbf{H} - \mathbf{G}^T = \mathbf{0}$ (to within numerical precision)
- Unit perturbations applied
- Floating point precision and underflow a concern with transmittance predictor formulation.
  - Some integrated predictors require the 3rd and 4th powers of absorber amount in the denominator. This is a problem for low absorber (e.g. water) amounts.
  - Current operational code will not run with floating point error handling enabled.

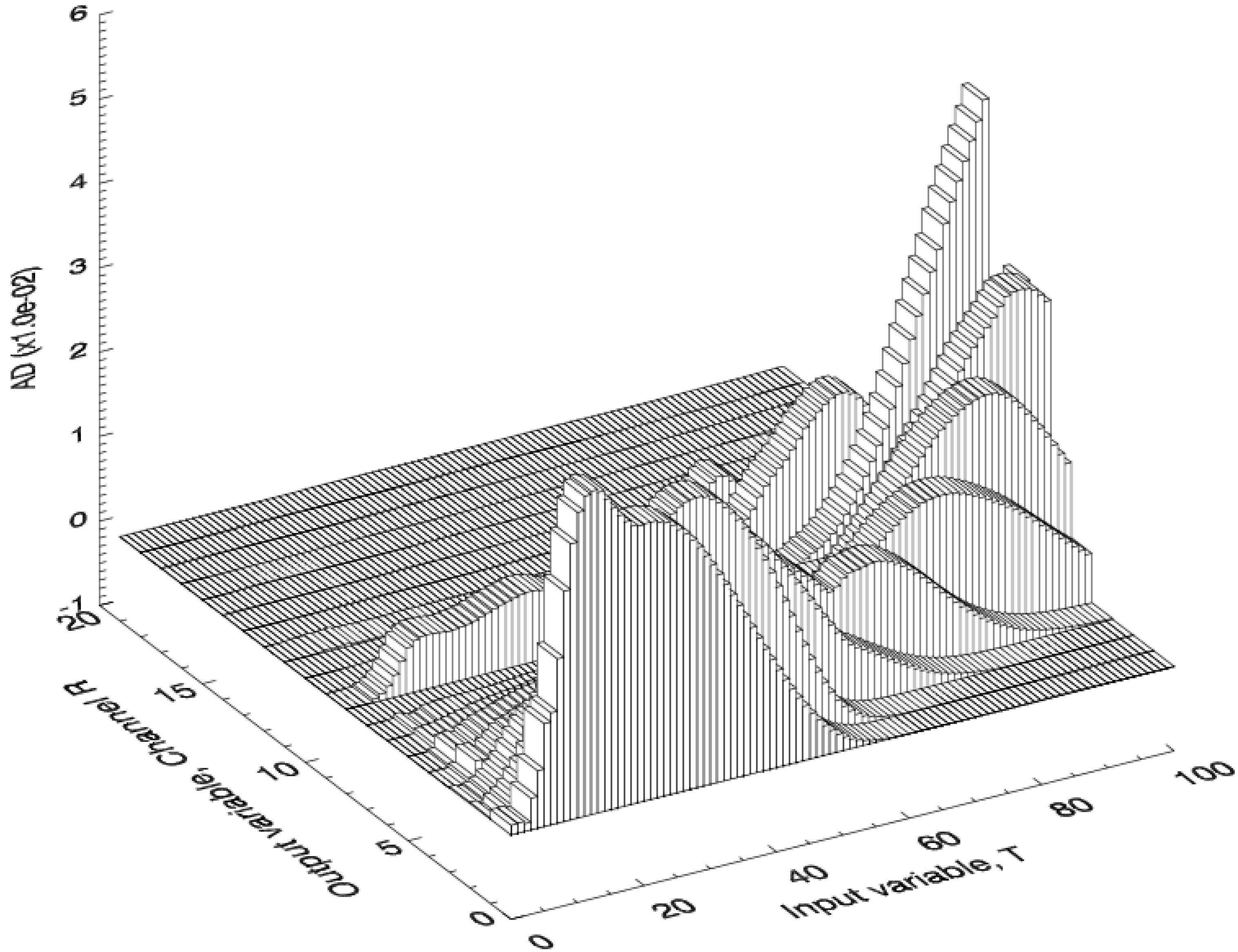

IDL 0
Absolute difference between TL and AD
predictors for profile # 1
OUTPUT VARIABLE : WET T***
INPUT VARIABLE : WET abs.
| TL - AD | (x1.0e-09)
0
2
4
6
8
Output variable, WET T*** layer
0
20
40
60
80
100
Input variable, WET abs. layer
0
20
40
60
80
100


IDL 0
Absolute difference between TL and AD
predictors for profile # 1
OUTPUT VARIABLE : OZO P***
INPUT VARIABLE : OZO abs.
| TL - AD | (x1.0e-12)
0.0
0.5
1.0
1.5
2.0
2.5
Output variable, OZO P*** layer
0
20
40
60
80
100
Input variable, OZO abs. layer
0
20
40
60
80
100

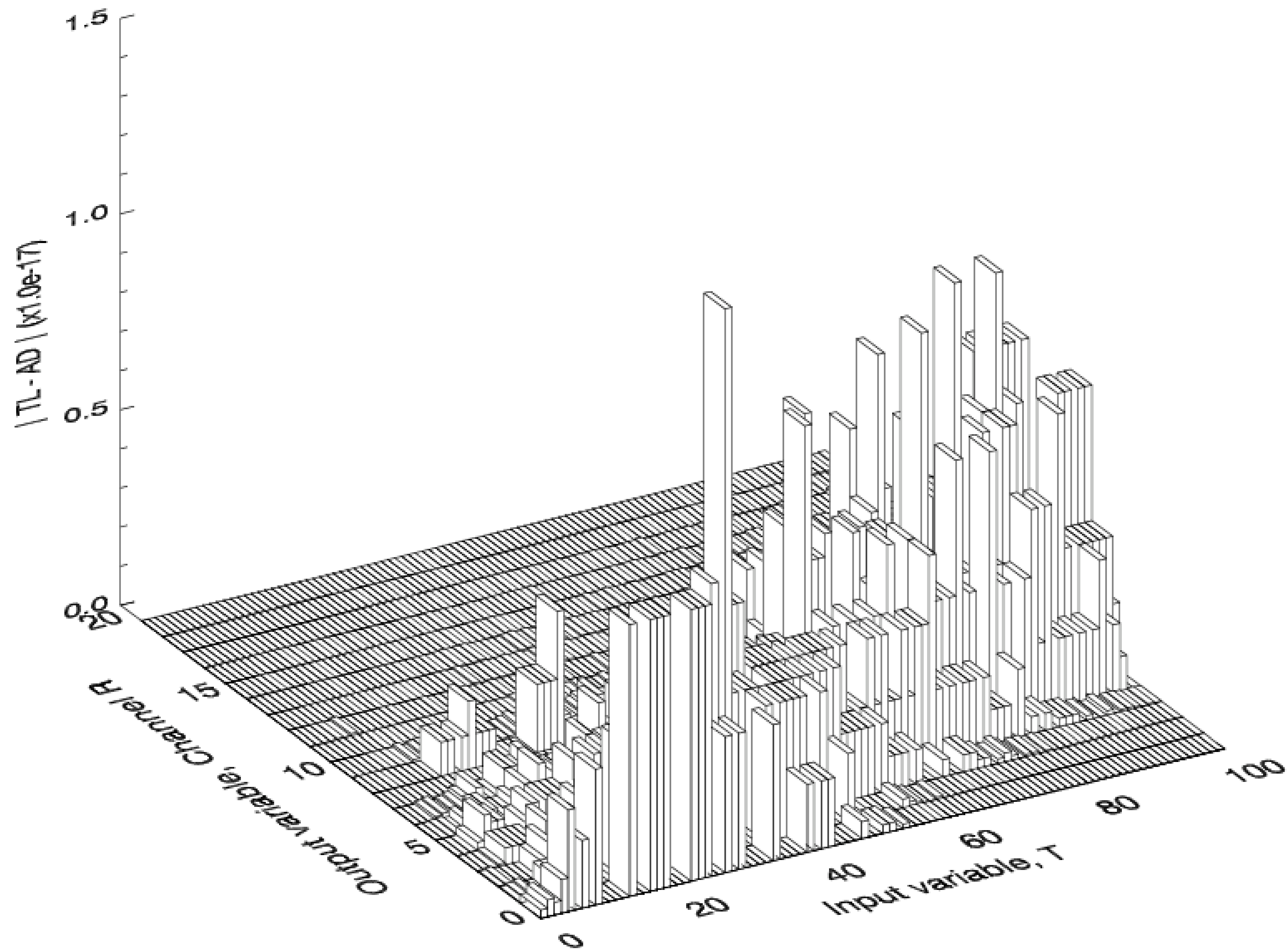
TL N16 HIRS channel radiances wrt T(p)



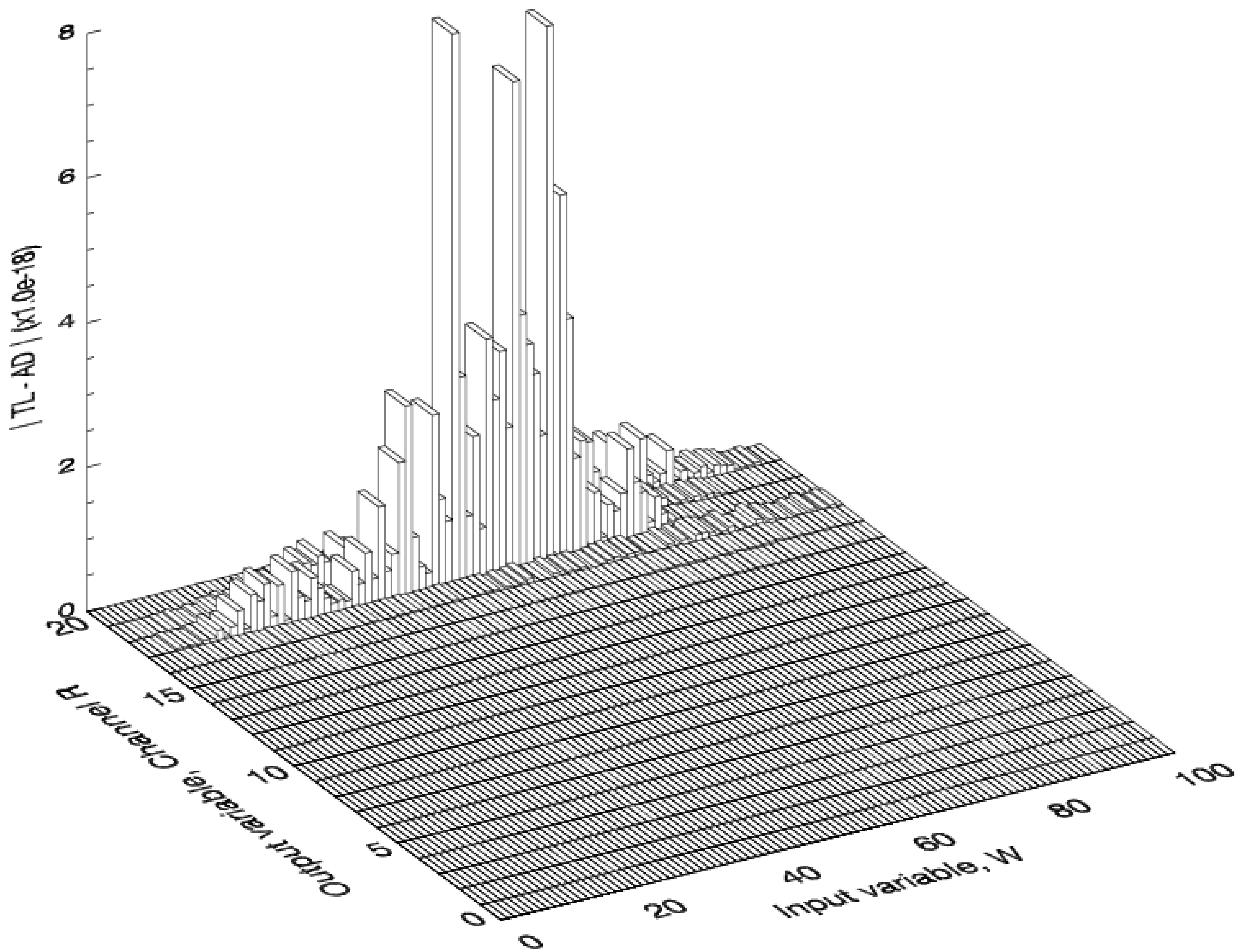
AD N16 HIRS channel radiances wrt T(p)



|TL-AD| difference for N16 HIRS wrt T(p)



|TL-AD| difference for N16 AMSU wrt W(p)



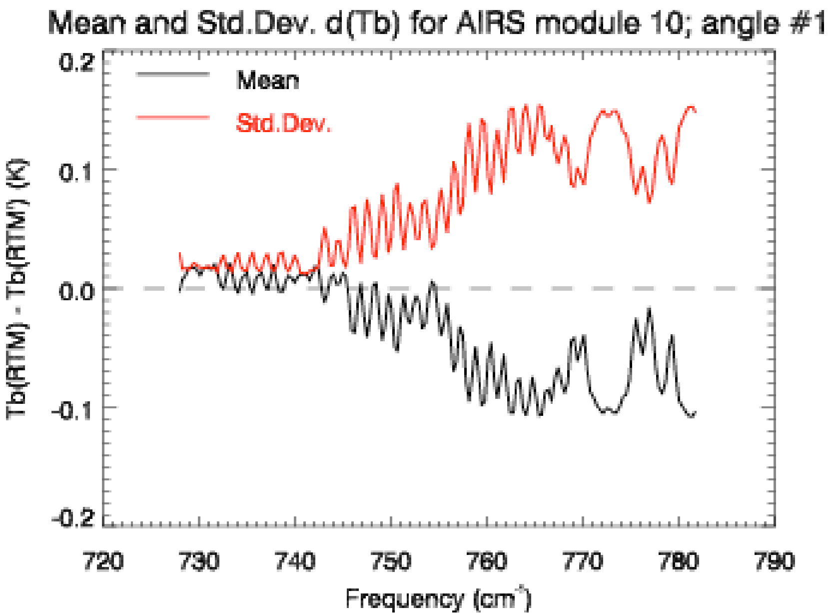
COMPARISON OF TOA T_b USING *RTM* AND *UMBC* GENERATED AIRS TRANSMITTANCES

Different profiles used in OPTRAN regression!

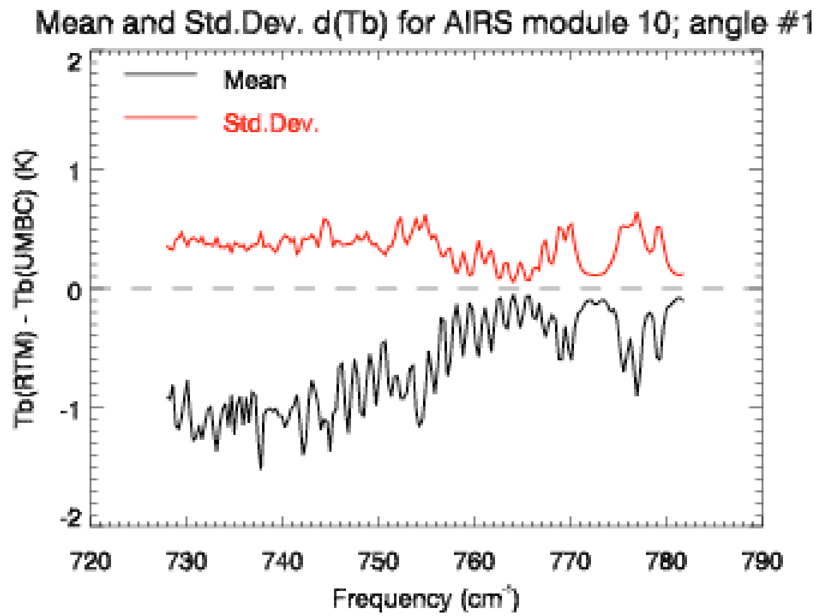
- kCARTA transmittance data from UMBC using their 48 profile dependent set.
- Two slightly different dependent profile sets:
  - 100-layer profiles accompanying transmittance data. What UMBC ASL used to generate transmittances. The “correct” profile set by definition.
  - 101-level profiles. What NESDIS and NCEP used to generate and test OPTRAN coefficients for AIRS. Call this an “incorrect” profile set.
- Profile differences are small and subtle but significant.
  - Testing RT impact of profile differences straightforward – run RTM with both sets.
  - Testing impact of profiles differences on accuracy of OPTRAN regression not as straightforward – at least in interpretation.
- Need 101-level profiles consistent with UMBC 100-layer profiles. Or derive coefficients using layer profiles.

AIRS Module 10

ΔT_b result for RTM transmittances *only* using the "correct" and "incorrect" profile sets.

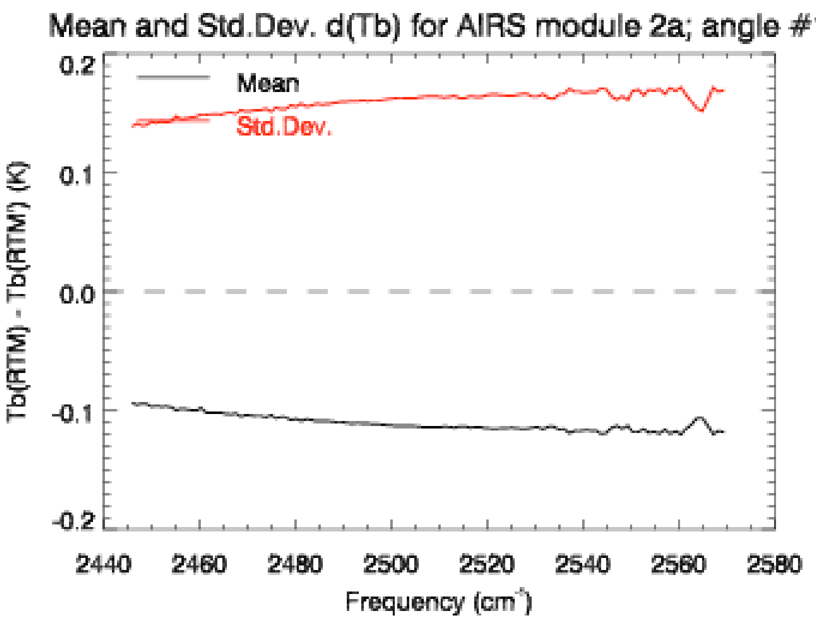


ΔT_b result for RTM and UMBC transmittances using only the "correct" profile set.

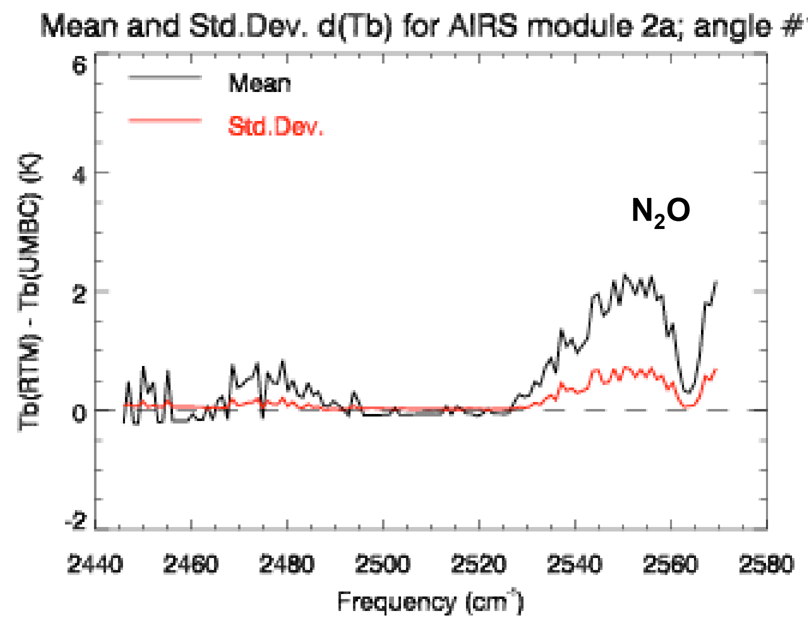


AIRS Module 2a

ΔT_b result for RTM transmittances *only* using the "correct" and "incorrect" profile sets.



ΔT_b result for RTM and UMBC transmittances using only the "correct" profile set.

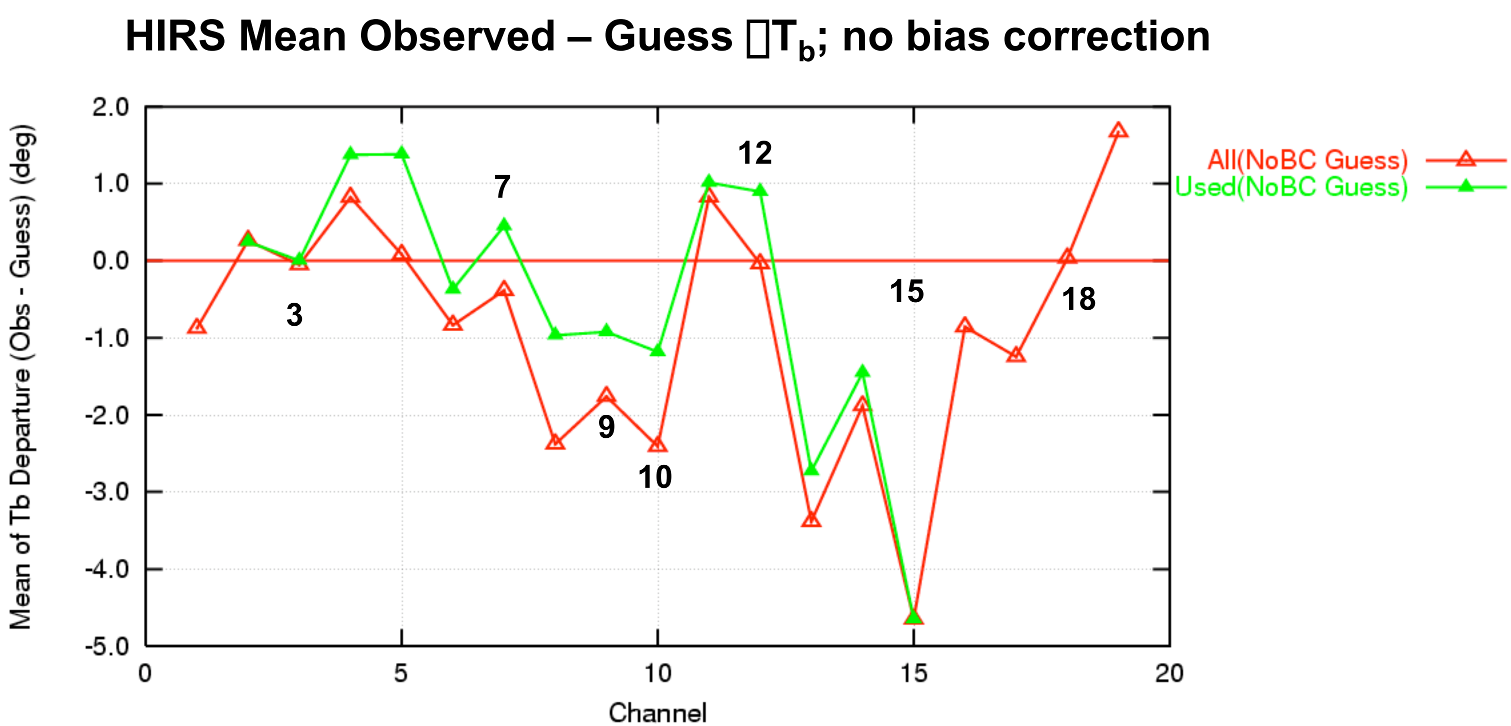


RTM COMPARISON IN GDAS

Operational and Parallel Analysis Runs

- Full analysis period: Oct. 30 0Z-21Z
- Analysis data period: Oct. 29 21Z – Oct. 30 21Z.
- Only NOAA-14 HIRS shown here.
- Guess for Operational and Parallel runs are different.
- Bias correction for Operational and Parallel runs calculated using one month window of data.
- Summary
  - Upgraded RTM improves bias in some channels, degrades it in others.
  - Variability is better in some channels with upgraded RTM, but differences are quite small.

Operational Run Mean ΔT_b

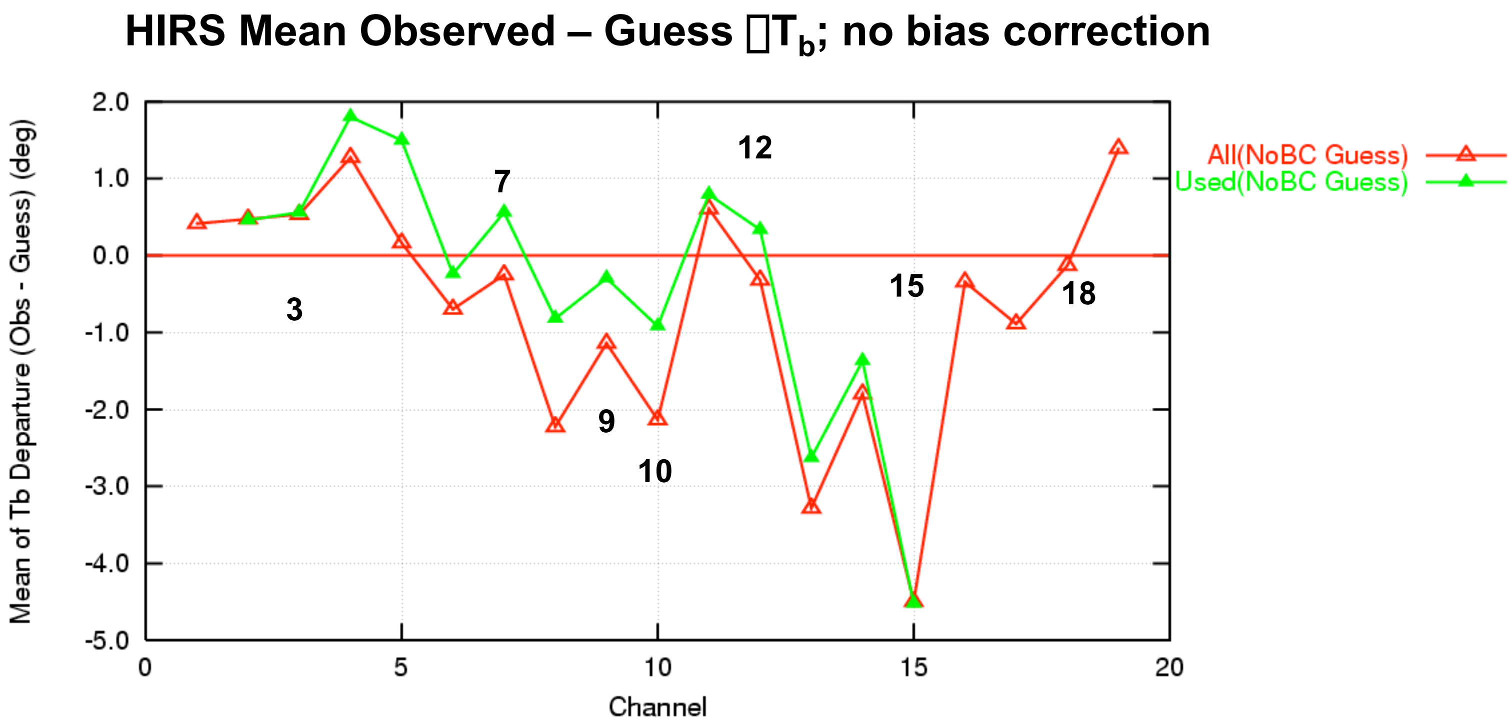


All: Gross quality controlled data.

Used: RT-dependent quality controlled data. (e.g. clear sky data for lower peaking channels)

NOTE: Ch. 1, 16-19 not assimilated.

Parallel Run Mean □T_b



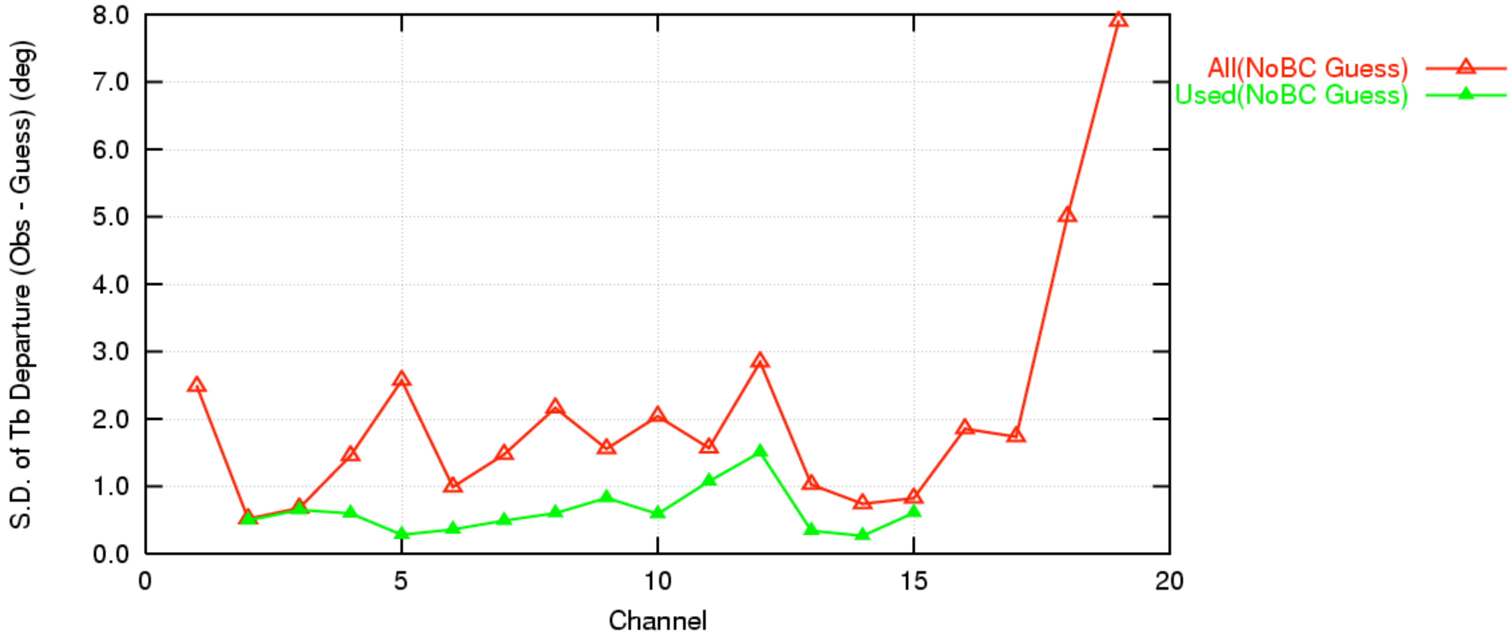
All: Gross quality controlled data.

Used: RT-dependent quality controlled data. (e.g. clear sky data for lower peaking channels)

NOTE: Ch. 1, 16-19 not assimilated.

Operational Run Std. Dev. ΔT_b

HIRS Std. Dev. Observed – Guess ΔT_b; no bias correction



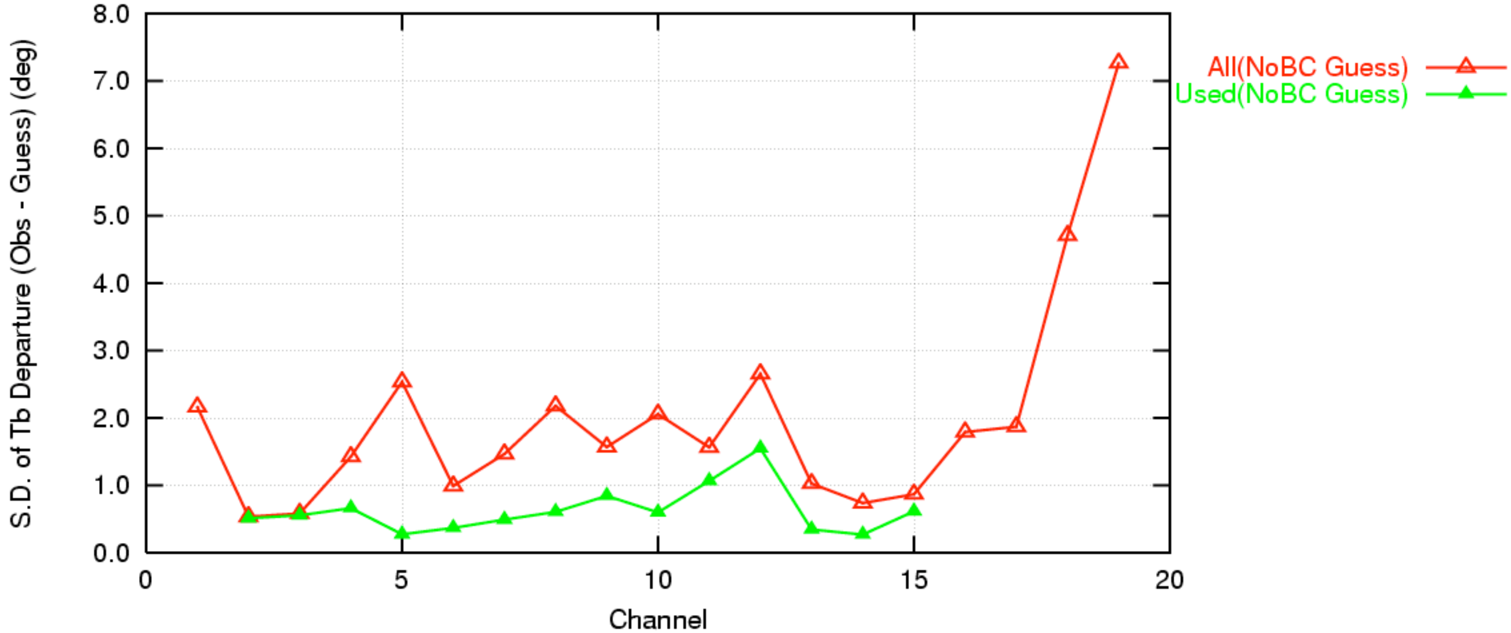
All: **Gross quality controlled data.**

Used: **RT-dependent quality controlled data. (e.g. clear sky data for lower peaking channels)**

NOTE: Ch. 1, 16-19 not assimilated.

Parallel Run Std.Dev. Tb

HIRS Std. Dev. Observed – Guess Tb; no bias correction



All: Gross quality controlled data.

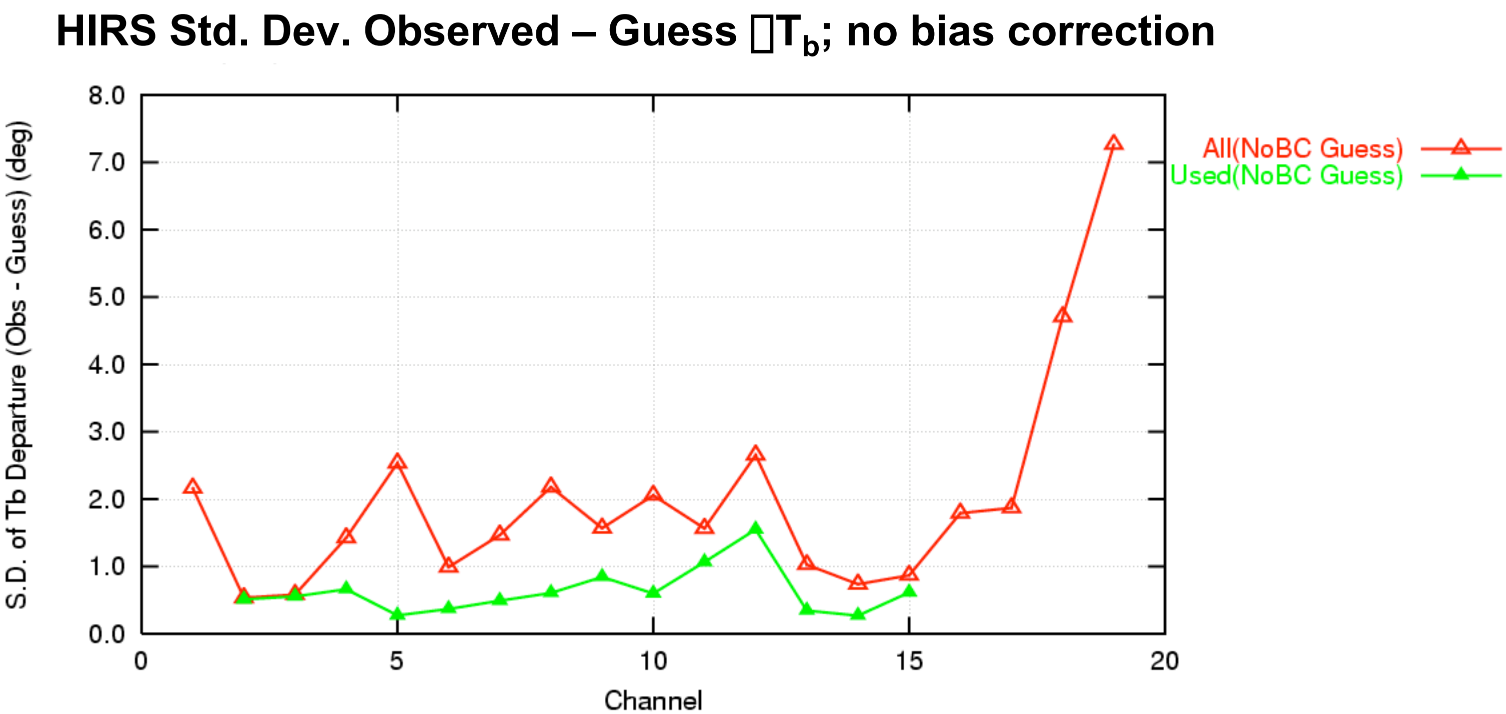
Used: RT-dependent quality controlled data. (e.g. clear sky data for lower peaking channels)

NOTE: Ch. 1, 16-19 not assimilated.

New Method Analysis Runs

- Memory requirement for OPTRAN coefficients may become prohibitive for high resolution IR sensors.
- Mr. Yoshihiko Tahara, visiting scientist from JMA, is investigating a different method – within the OPTRAN framework – to predict absorption coefficient and transmittance profiles.
  - Currently, OPTRAN requires 1800 *available* coefficients for each channel; 6 coefficients (offset + 5 predictors) for 300 absorber layers.
  - Current status of research requires 48-64 coefficients per channel.
- New method fits the vertical absorption coefficient profile and this reduces the need for a large number of coefficients.
- Current tests have been performed using localised changes to upgraded RTM source.

Parallel Run Std.Dev. □T_b



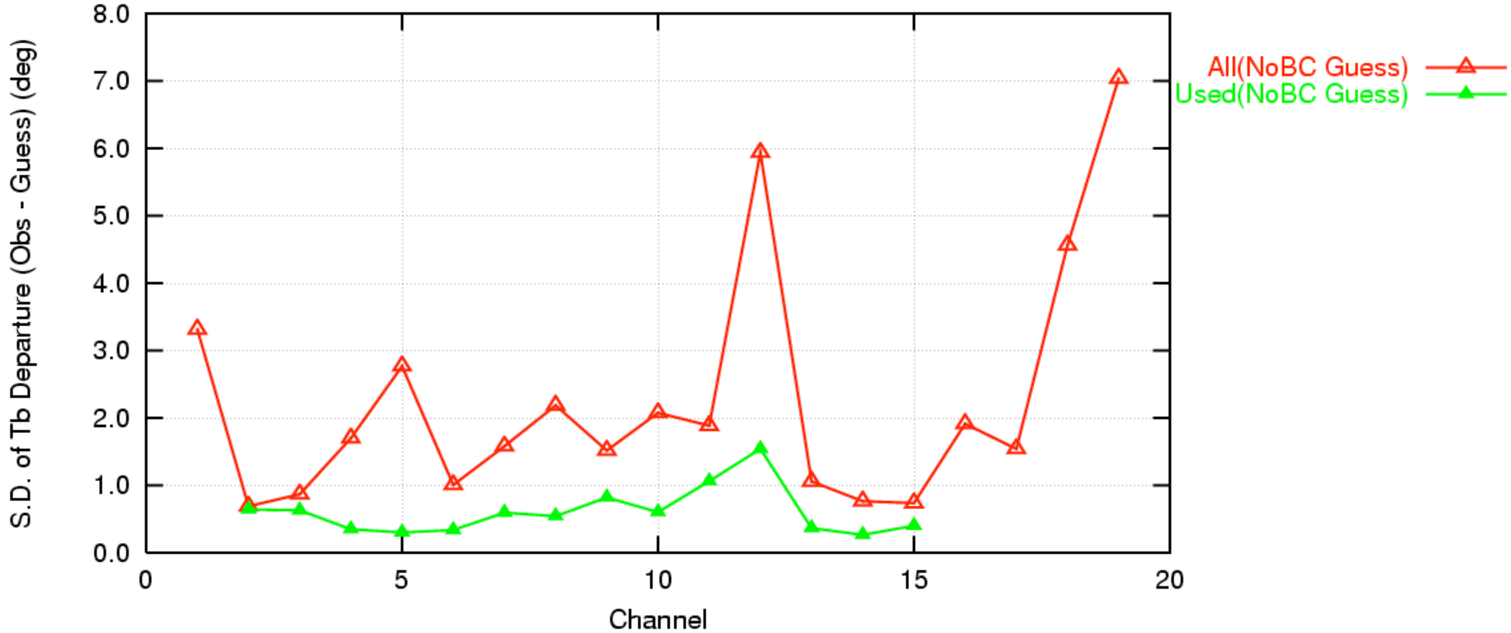
All: Gross quality controlled data.

Used: RT-dependent quality controlled data. (e.g. clear sky data for lower peaking channels)

NOTE: Ch. 1, 16-19 not assimilated.

NewMethod Test Run Std.Dev. ΔT_b

HIRS Std. Dev. Observed – Guess ΔT_b; no bias correction



All: Gross quality controlled data.

Used: RT-dependent quality controlled data. (e.g. clear sky data for lower peaking channels)

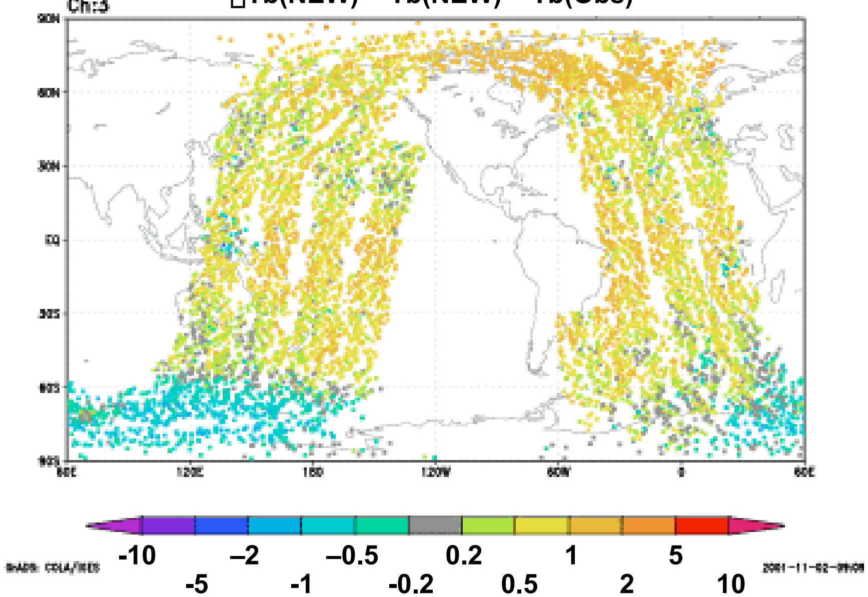
NOTE: Ch. 1, 16-19 not assimilated.

Global plots of ΔT_b

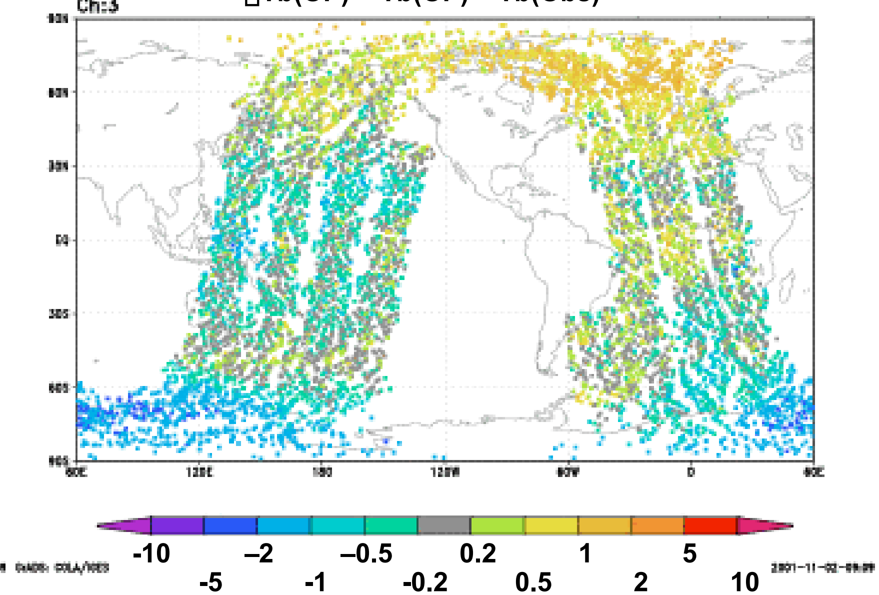
- Data used in plots is from the 18Z analysis.
- Differences of current operational RTM (OP) and upgraded RTM (NEW) with observations (Obs).
- Comparisons of differences:
  - $\Delta|\Delta Tb| = |\Delta Tb(OP\text{-}Obs)| - |\Delta Tb(NEW\text{-}Obs)|$
  - If $\Delta|\Delta Tb|$ is
    - $> 0K$, then upgraded model is performing better than operational model.
    - $< 0K$, then operational model is performing better than upgraded model.
  - This comparison doesn't take into account any improvement in variability (which for the IR are small).
- Results with and without bias-correction shown.
  - Non-bias corrected results important for RTM provider.
  - Bias corrected results important for NWP users.

HIRS Ch.3 comparison, no bias correction

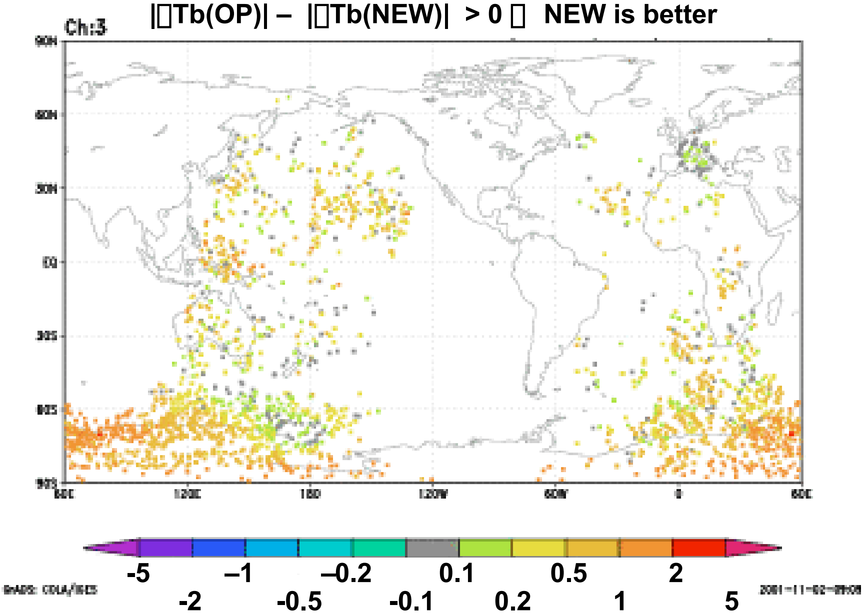
□Tb(NEW) = Tb(NEW) – Tb(Obs)



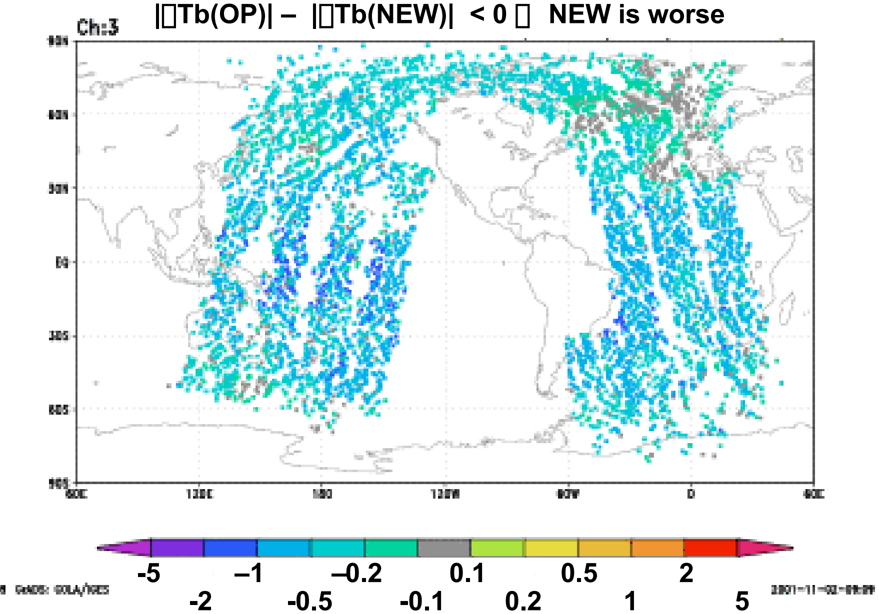
□Tb(OP) = Tb(OP) – Tb(Obs)



|□Tb(OP)| – |□Tb(NEW)| > 0 □ NEW is better

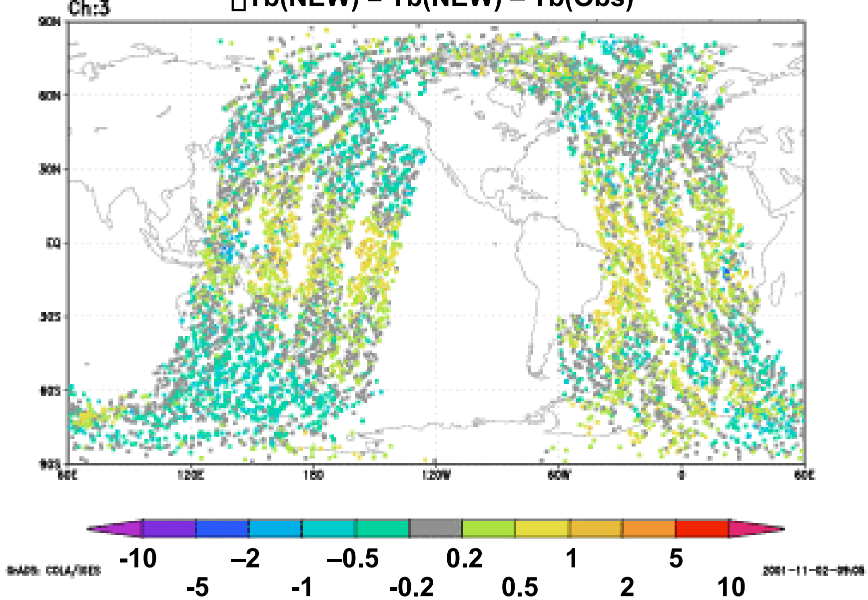


|□Tb(OP)| – |□Tb(NEW)| < 0 □ NEW is worse

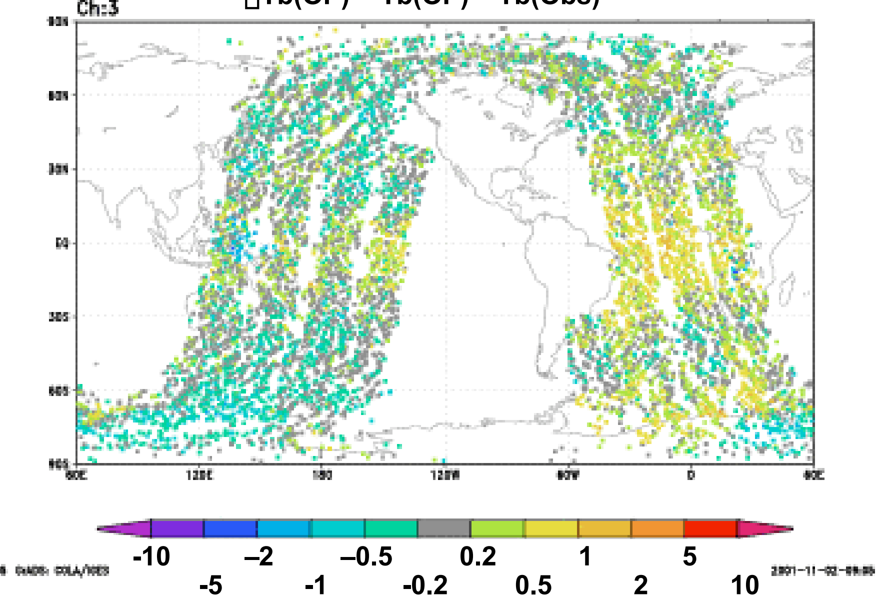


HIRS Ch.3 comparison, with bias correction

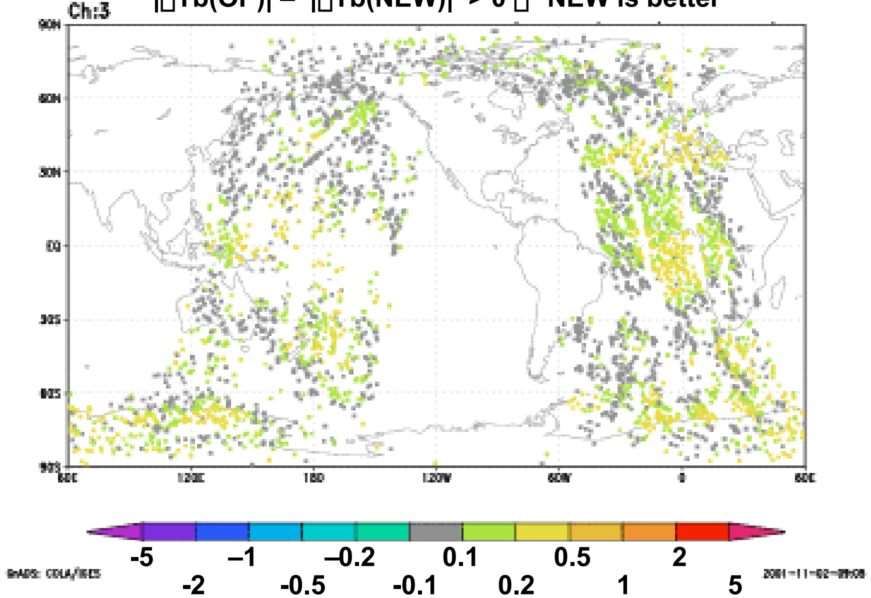
□Tb(NEW) = Tb(NEW) – Tb(Obs)



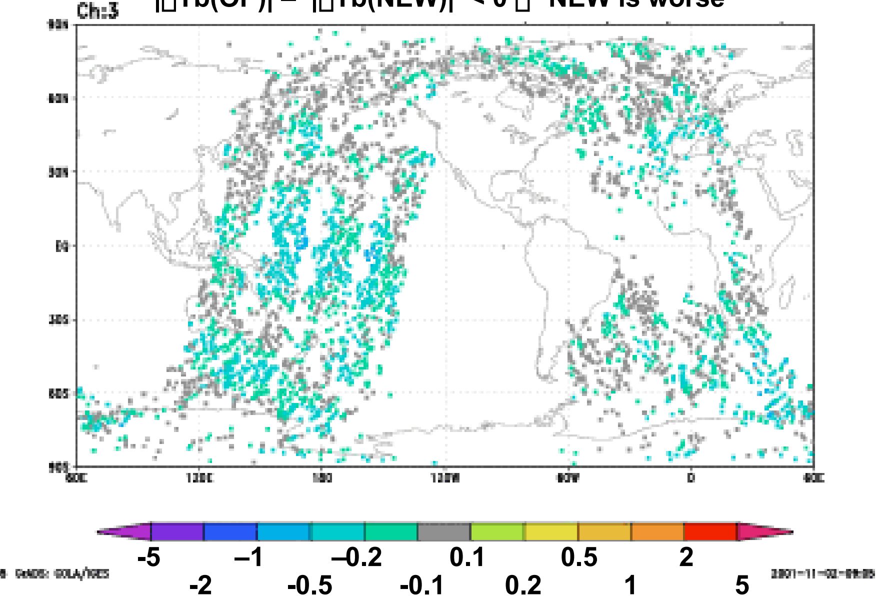
□Tb(OP) = Tb(OP) – Tb(Obs)



|□Tb(OP)| – |□Tb(NEW)| > 0 □ NEW is better

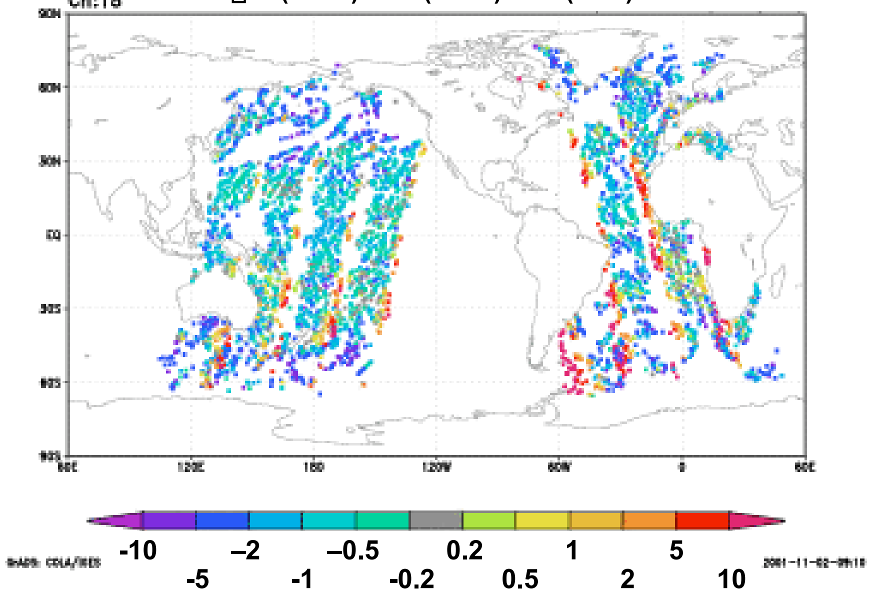


|□Tb(OP)| – |□Tb(NEW)| < 0 □ NEW is worse

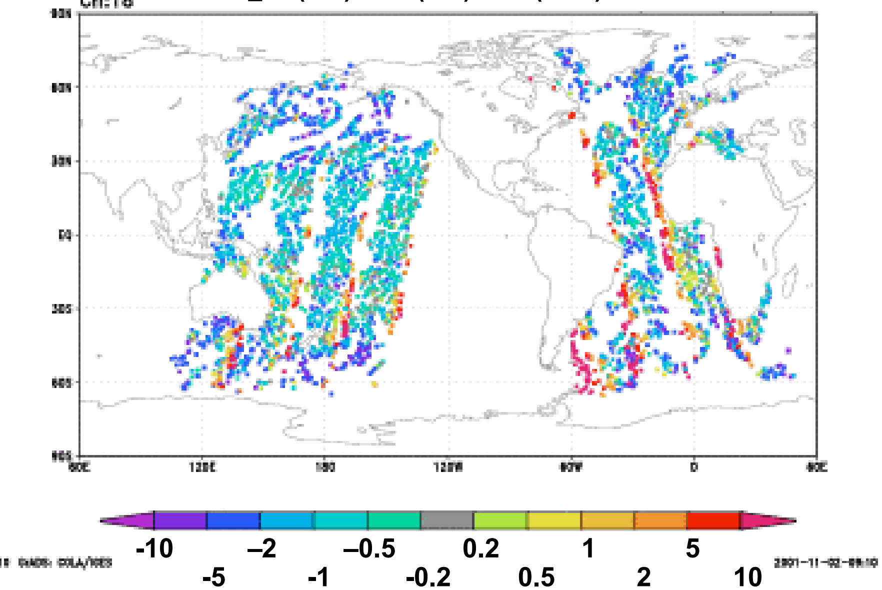


HIRS Ch.18 comparison, no bias correction

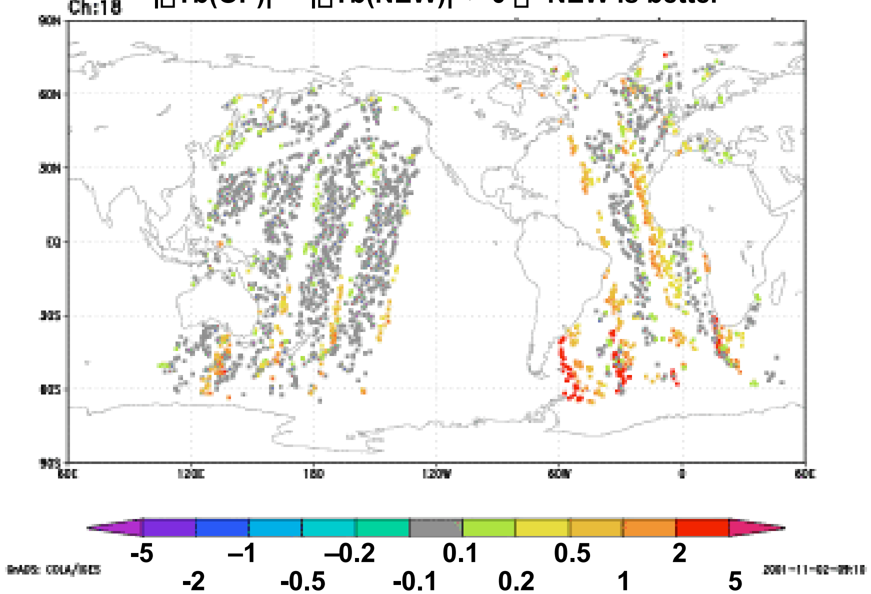
ΔTb(NEW) = Tb(NEW) – Tb(Obs)



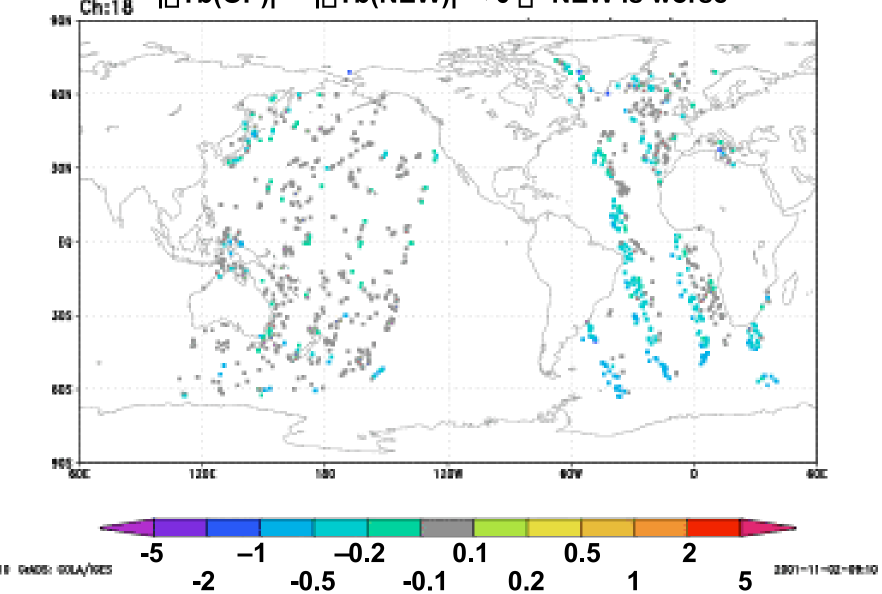
ΔTb(OP) = Tb(OP) – Tb(Obs)



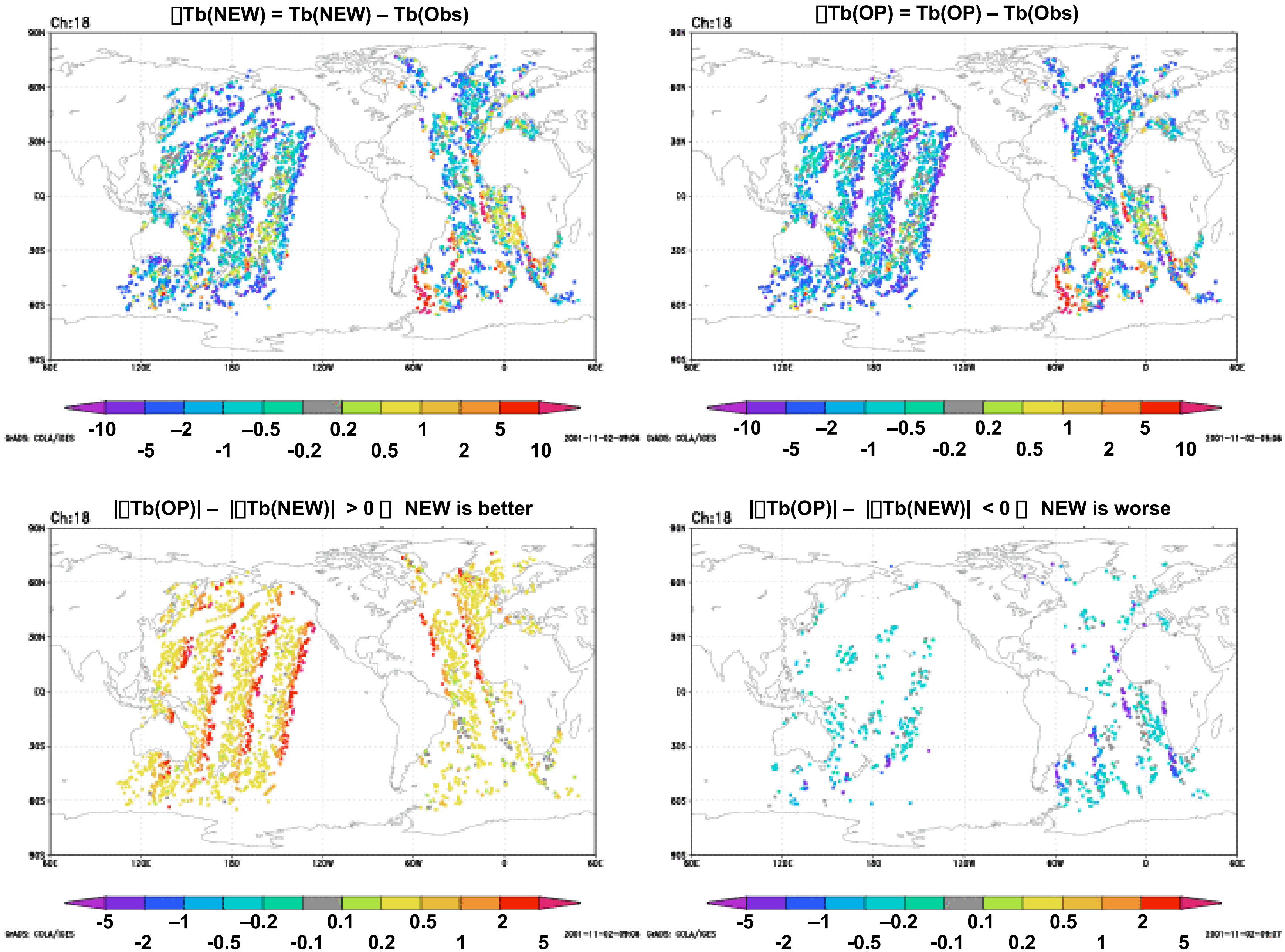
|ΔTb(OP)| – |ΔTb(NEW)| > 0 ⇒ NEW is better



|ΔTb(OP)| – |ΔTb(NEW)| < 0 ⇒ NEW is worse



HIRS Ch.18 comparison, with bias correction



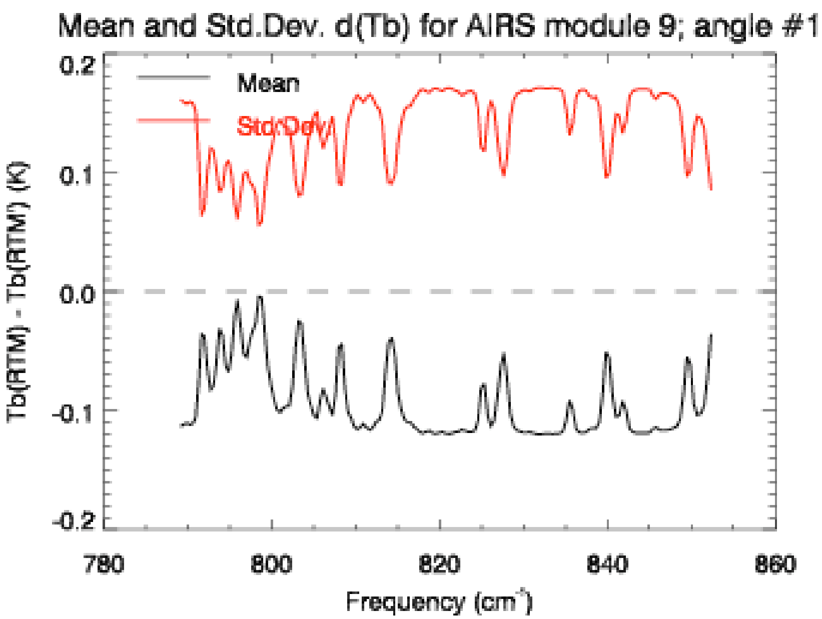
To Do

- Resolve profile set differences – not just dependent set, but any level→ layer profile set.
- Work with Larry and Tom to improve fit statistics.
  - Currently dry (fixed) gas fits are good. Water vapor and ozone need some work.
  - Resolve absorption feature differences in AIRS LBL–regression spectra (e.g. CFCs, CH_4, N_2O)
- Further improvement of Y. Tahara's model.
- Option of Wu-Smith sea surface emissivity model in RTM.
- LBL transmittances.
  - Designing code to process LBL output to instrument transmittances.
  - Upgrade of μwave LBL code.
  - ***All*** instrument transmittances need to be recalculated to coincide with UMBC dependent profile set.
  - Include larger angles in regression fits for solar calculation.

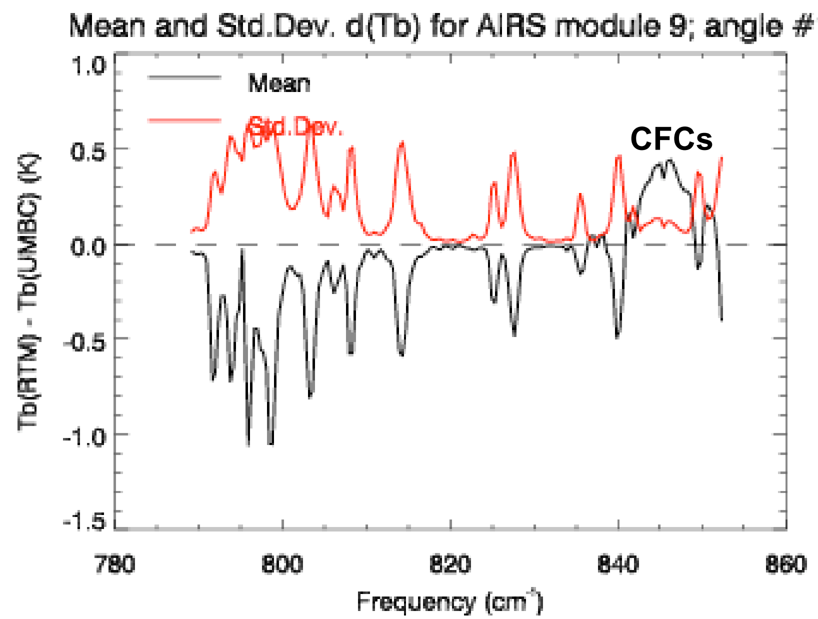
The End

AIRS Module 9

□T_b result for RTM transmittances *only* using the “correct” and “incorrect” profile sets.

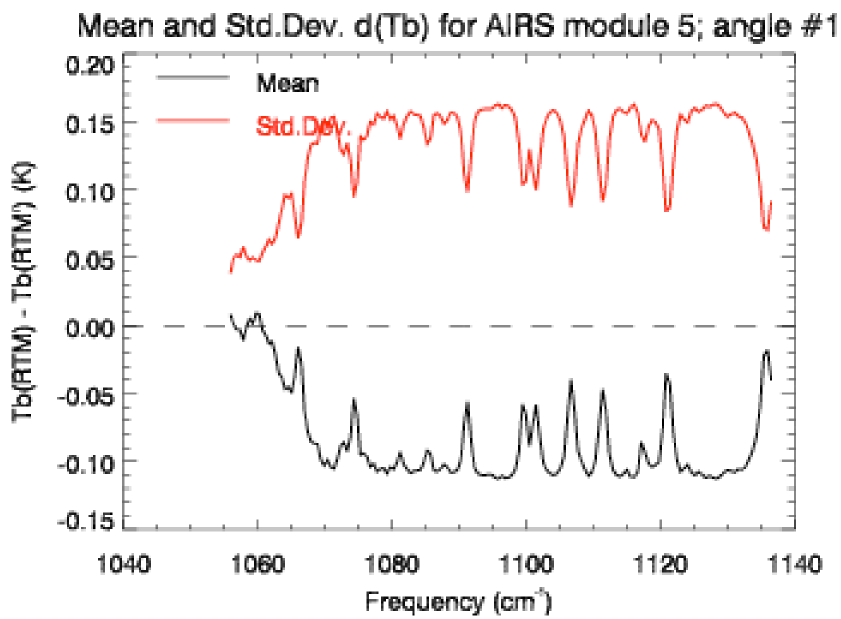


□T_b result for RTM and UMBC transmittances using only the “correct” profile set.

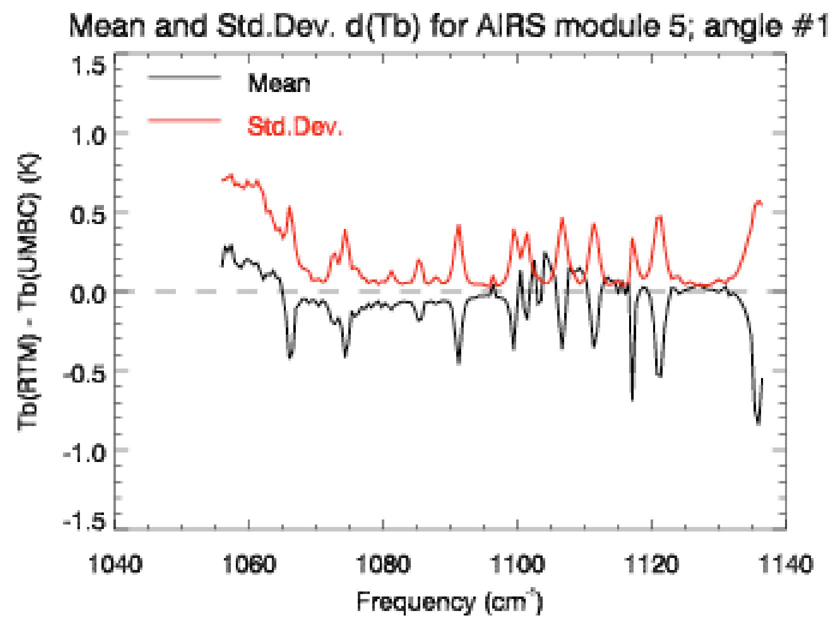


AIRS Module 5

ΔT_b result for RTM transmittances *only* using the "correct" and "incorrect" profile sets.

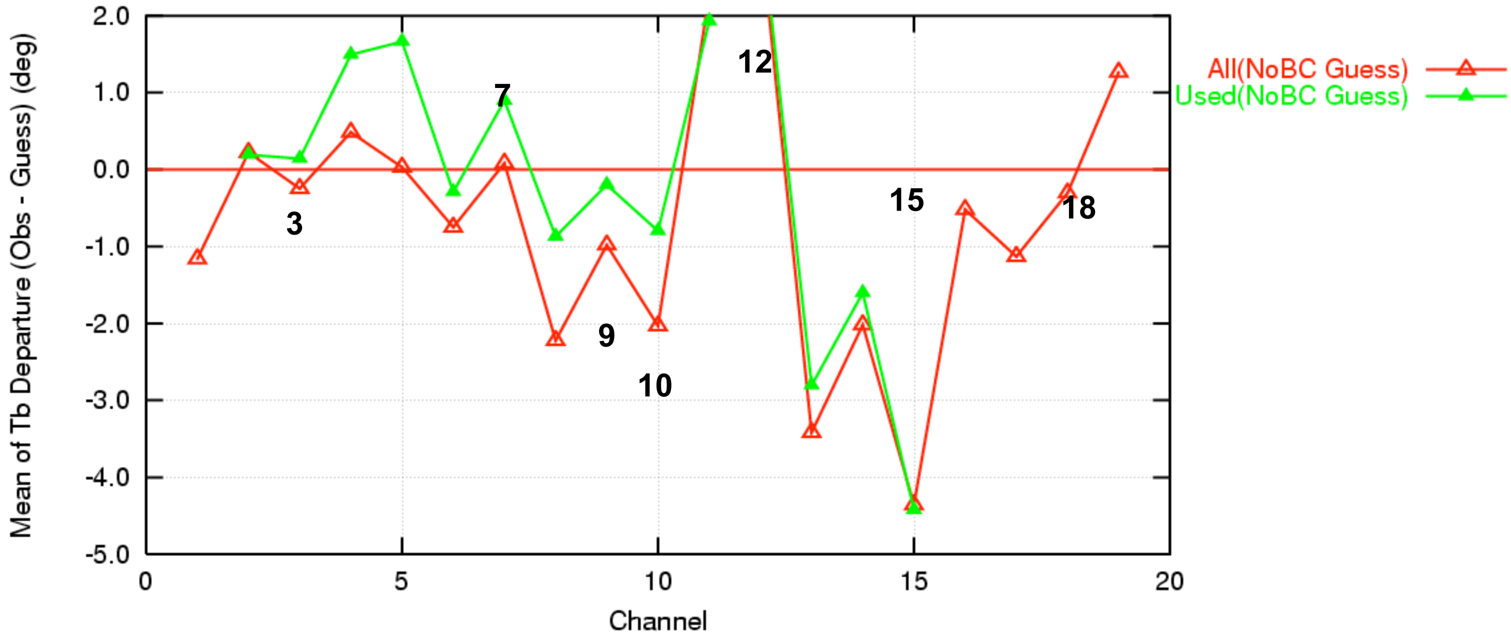


ΔT_b result for RTM and UMBC transmittances using only the "correct" profile set.



NewMethod Test Run Mean ΔT_b

HIRS Mean Observed – Guess ΔT_b; no bias correction

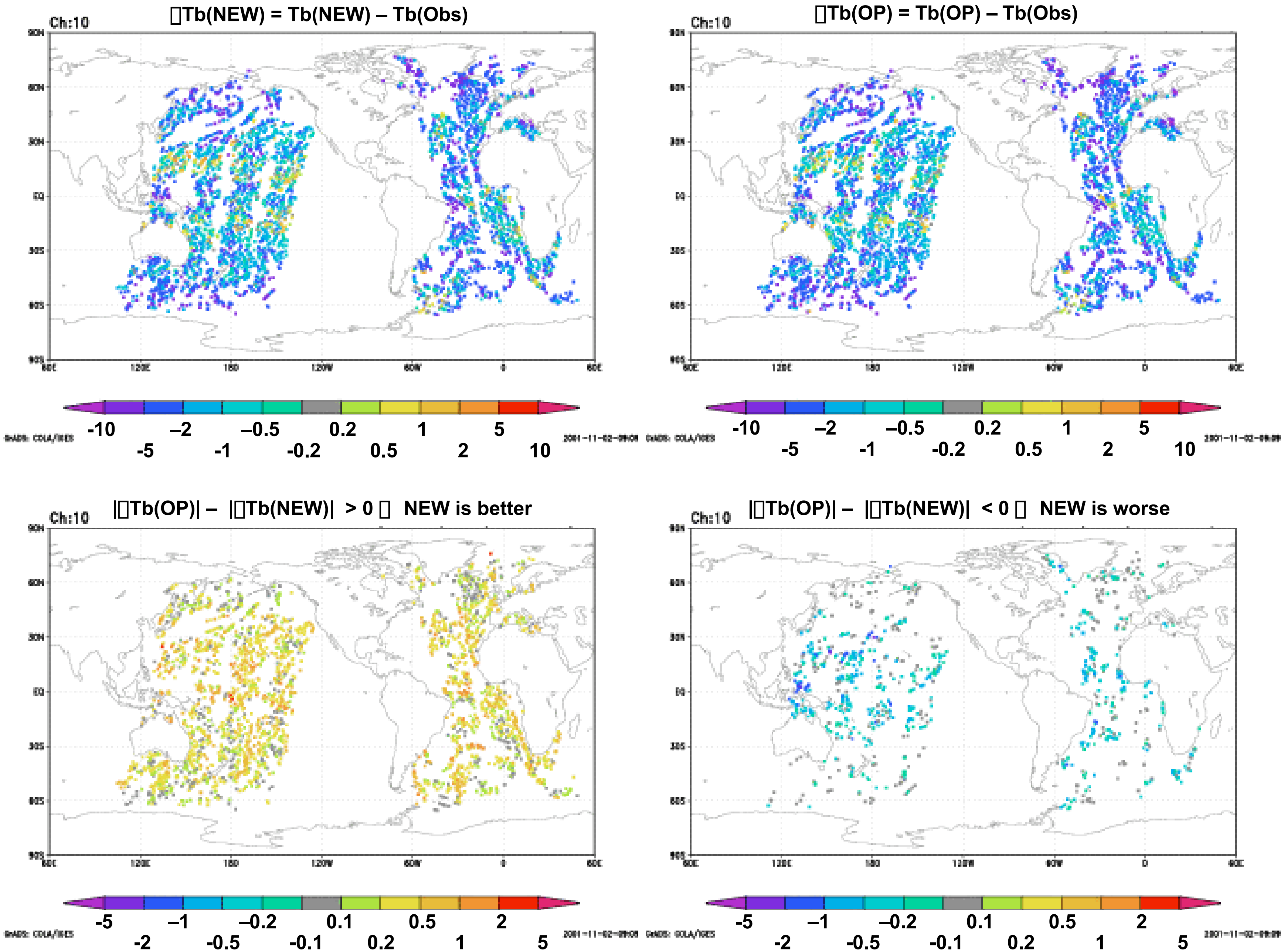


All: Gross quality controlled data.

Used: RT-dependent quality controlled data. (e.g. clear sky data for lower peaking channels)

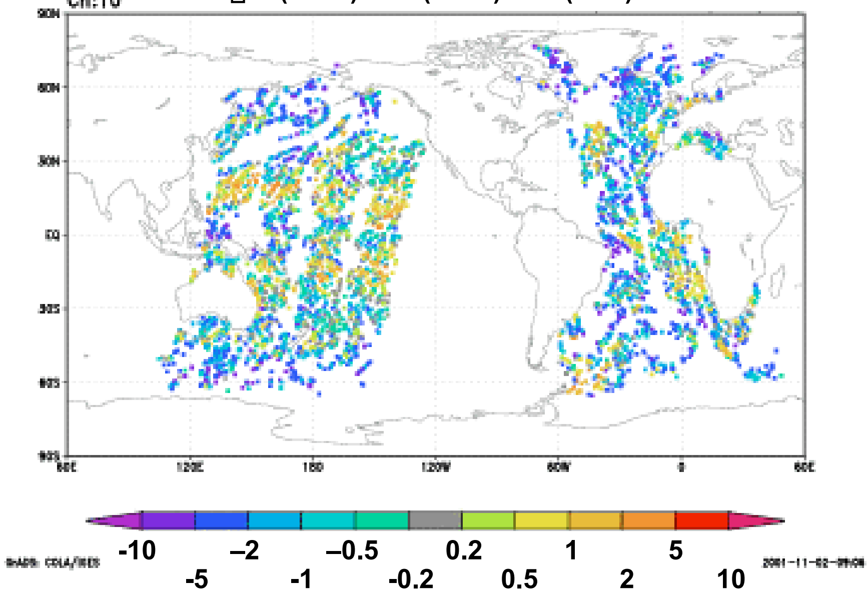
NOTE: Ch. 1, 16-19 not assimilated.

HIRS Ch.10 comparison, no bias correction

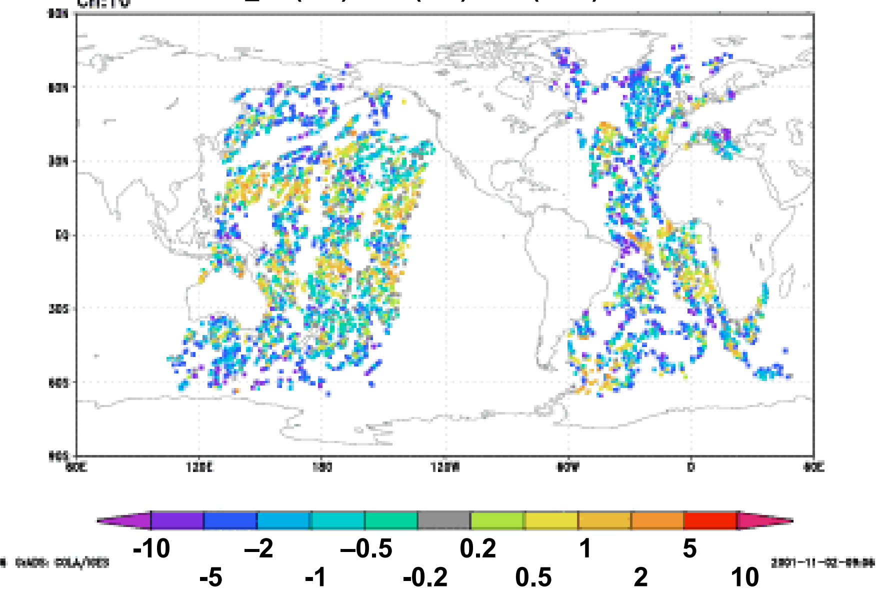


HIRS Ch.10 comparison, with bias correction

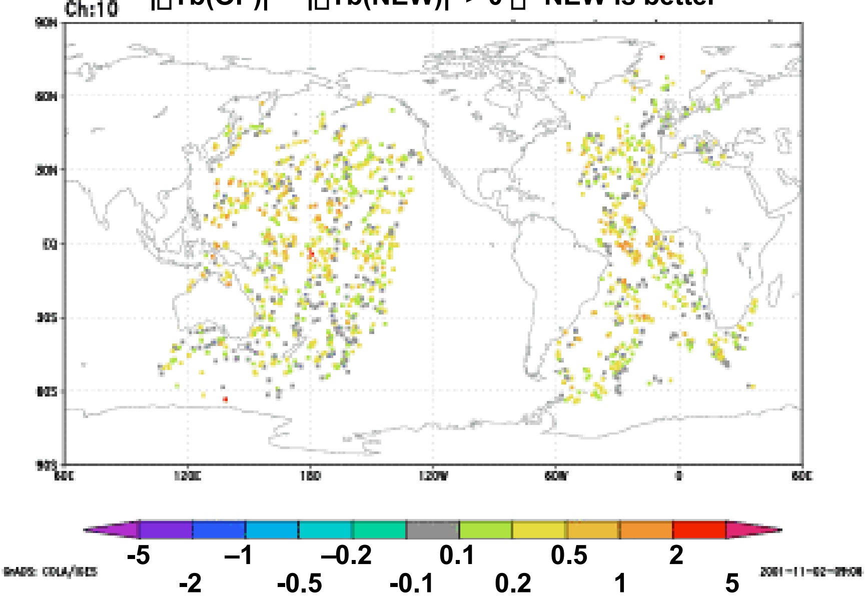
ΔTb(NEW) = Tb(NEW) – Tb(Obs)



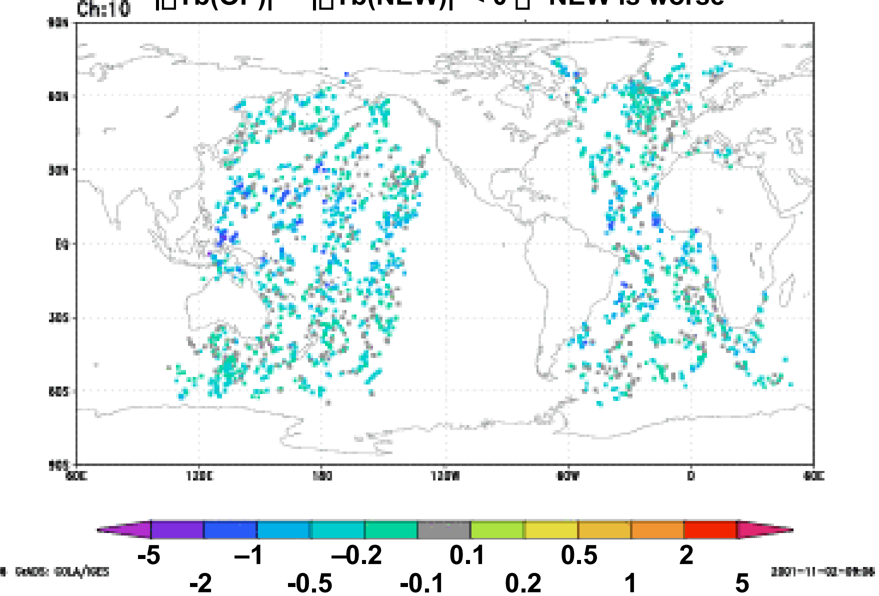
ΔTb(OP) = Tb(OP) – Tb(Obs)



|ΔTb(OP)| – |ΔTb(NEW)| > 0 ⇒ NEW is better

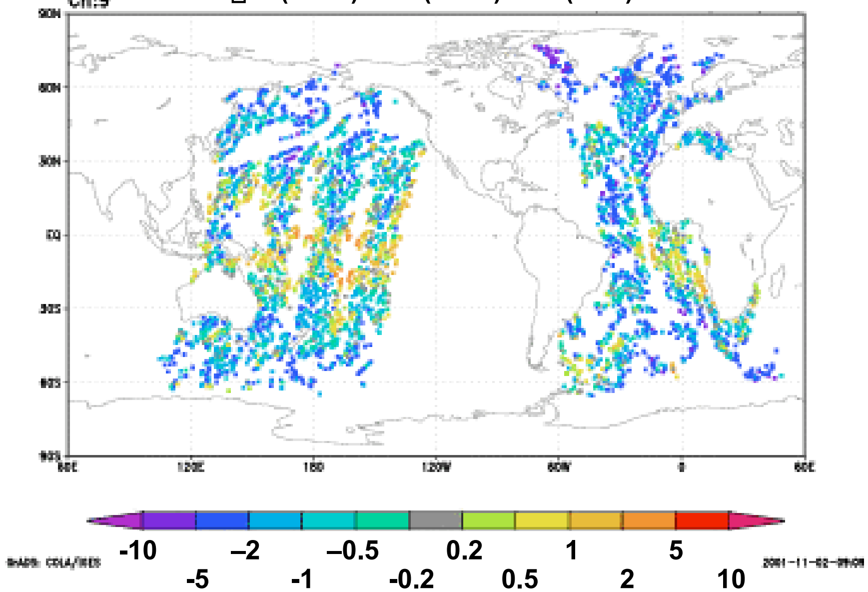


|ΔTb(OP)| – |ΔTb(NEW)| < 0 ⇒ NEW is worse

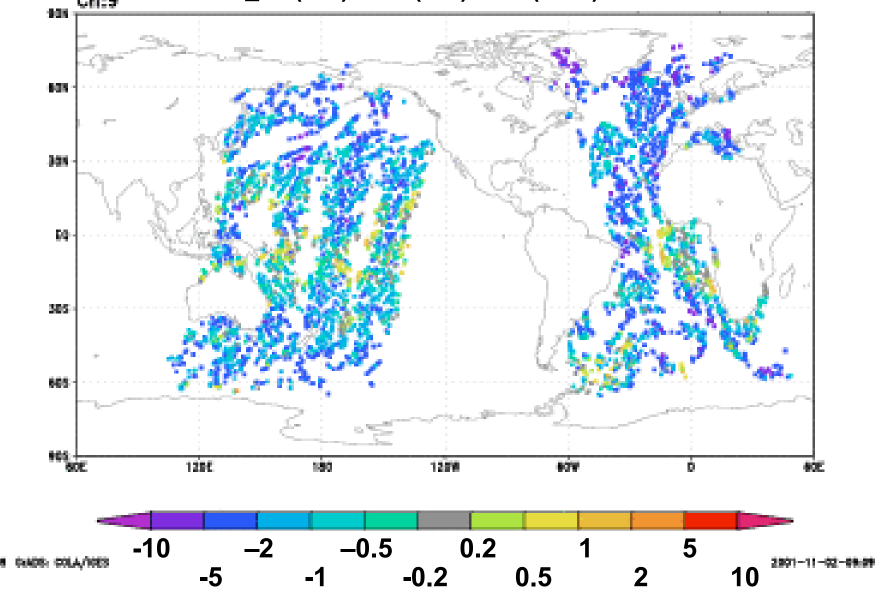


HIRS Ch.9 comparison, no bias correction

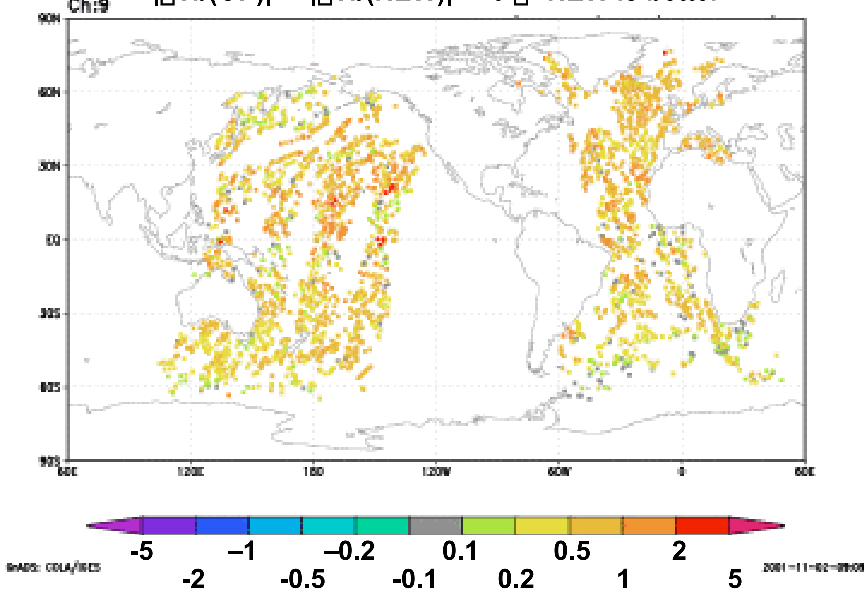
□Tb(NEW) = Tb(NEW) – Tb(Obs)



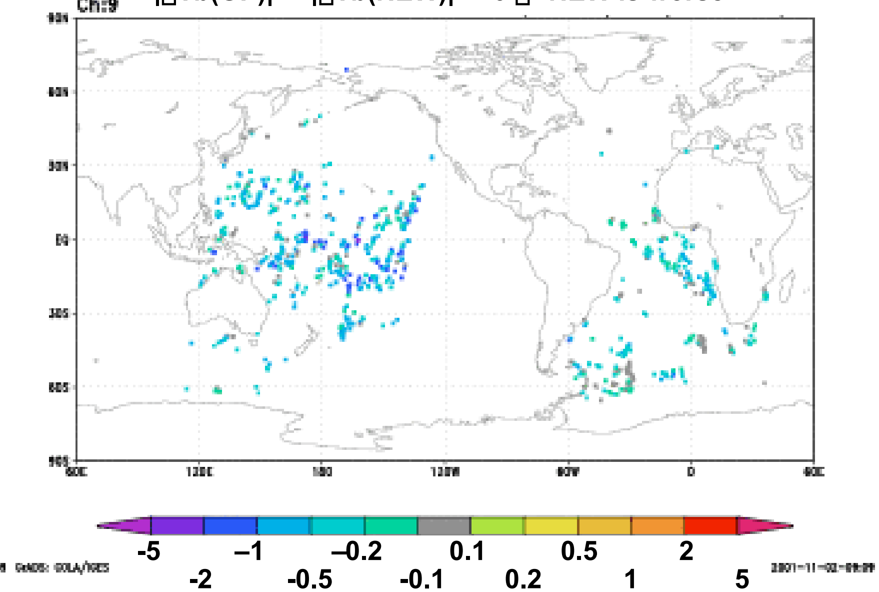
□Tb(OP) = Tb(OP) – Tb(Obs)



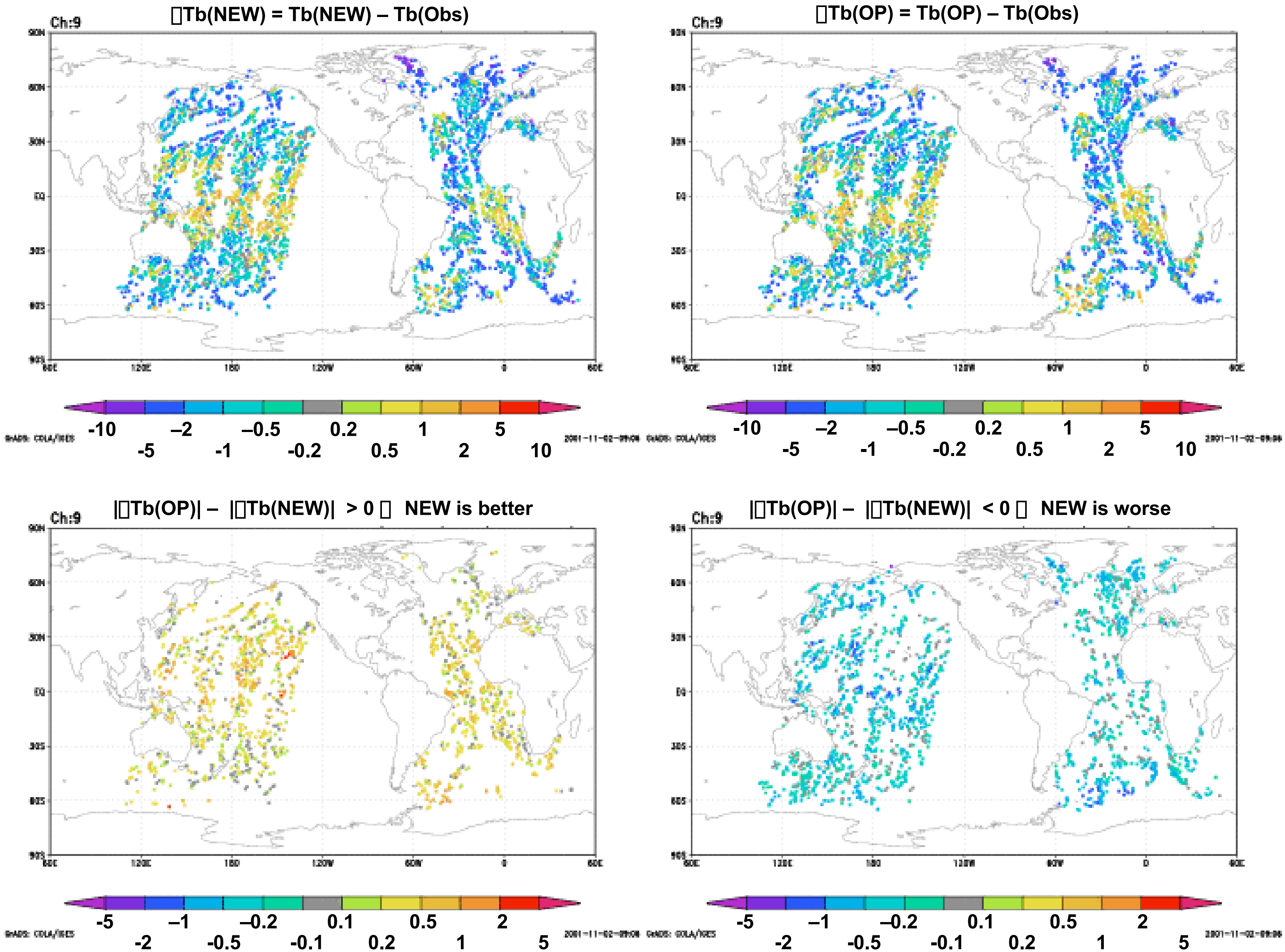
|□Tb(OP)| – |□Tb(NEW)| > 0 □ NEW is better



|□Tb(OP)| – |□Tb(NEW)| < 0 □ NEW is worse

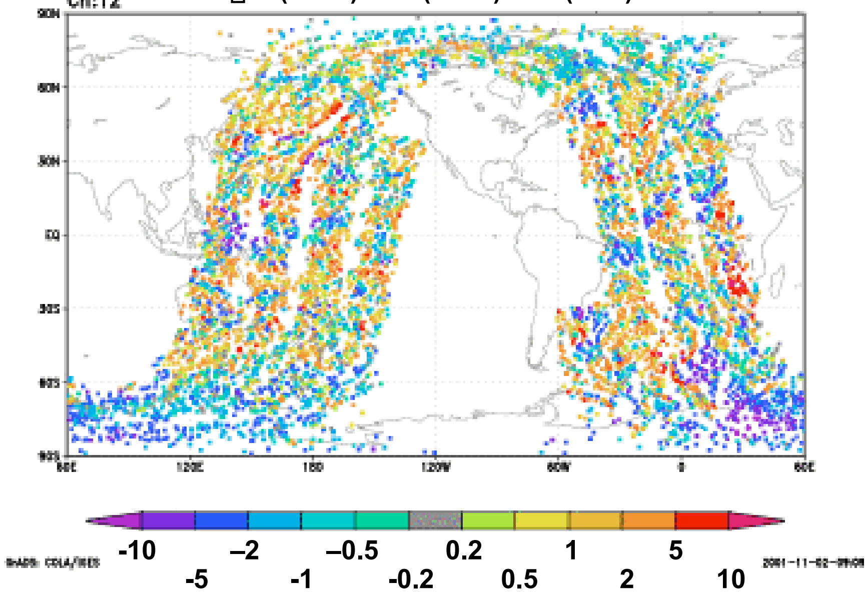


HIRS Ch.9 comparison, with bias correction

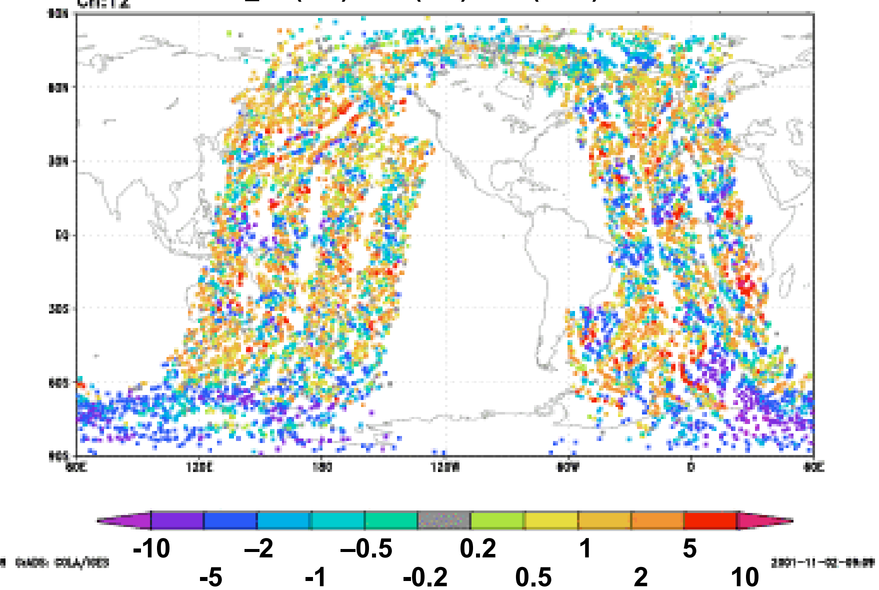


HIRS Ch.12 comparison, no bias correction

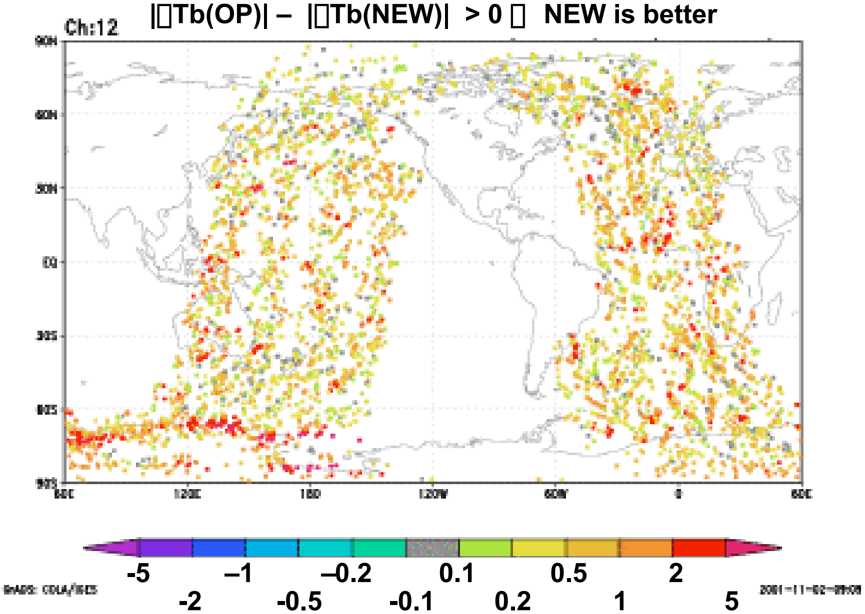
ΔTb(NEW) = Tb(NEW) – Tb(Obs)



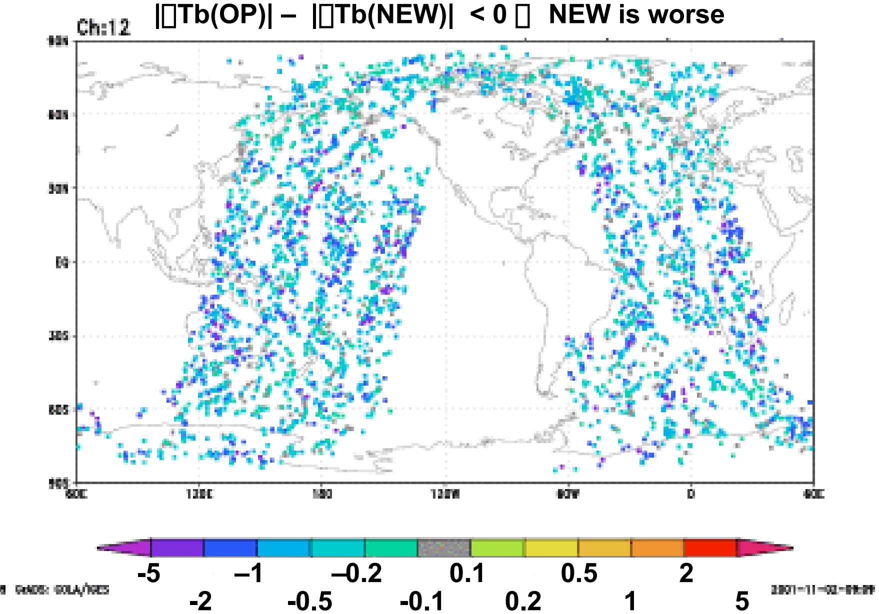
ΔTb(OP) = Tb(OP) – Tb(Obs)



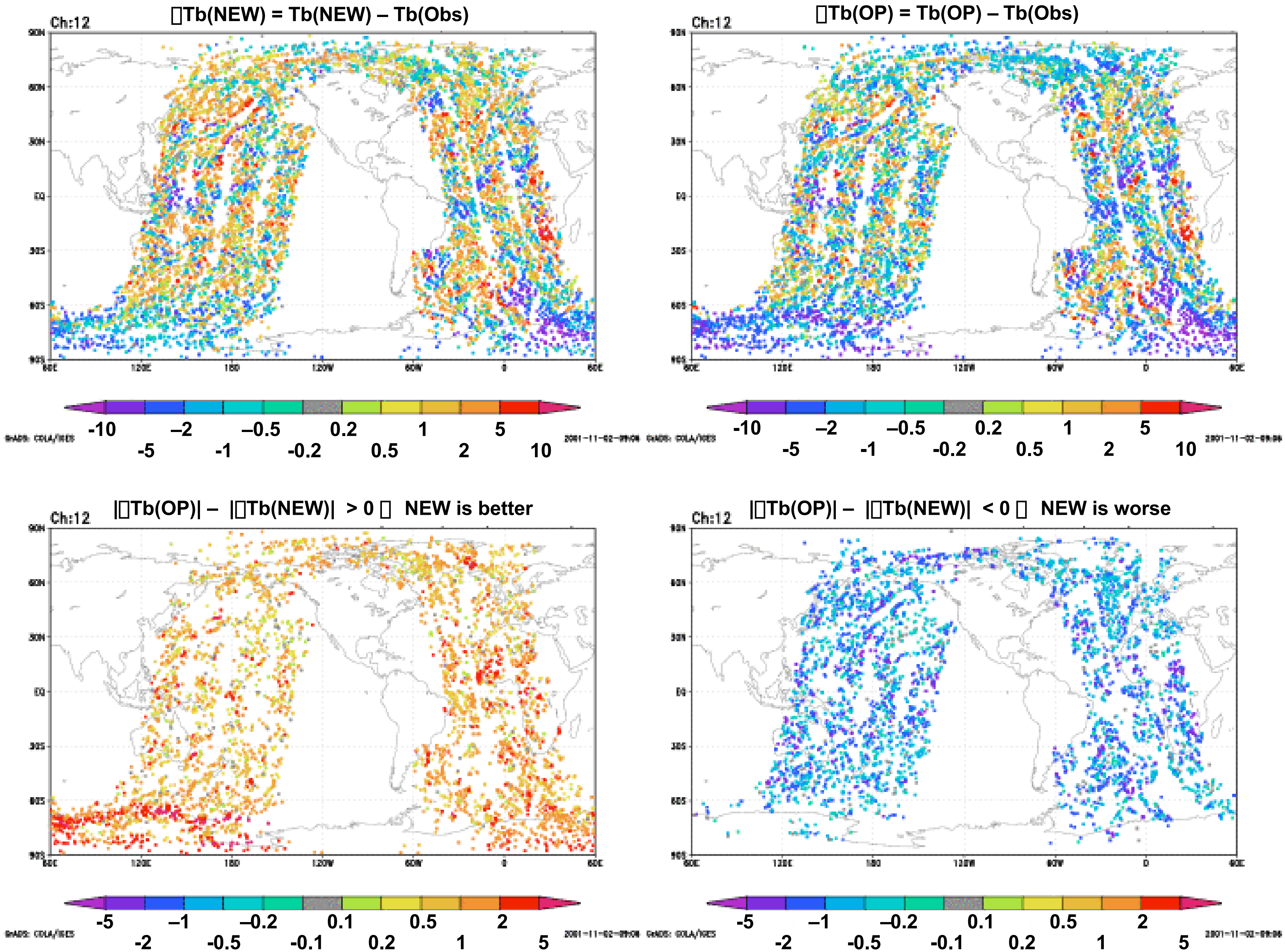
|ΔTb(OP)| – |ΔTb(NEW)| > 0 → NEW is better



|ΔTb(OP)| – |ΔTb(NEW)| < 0 → NEW is worse

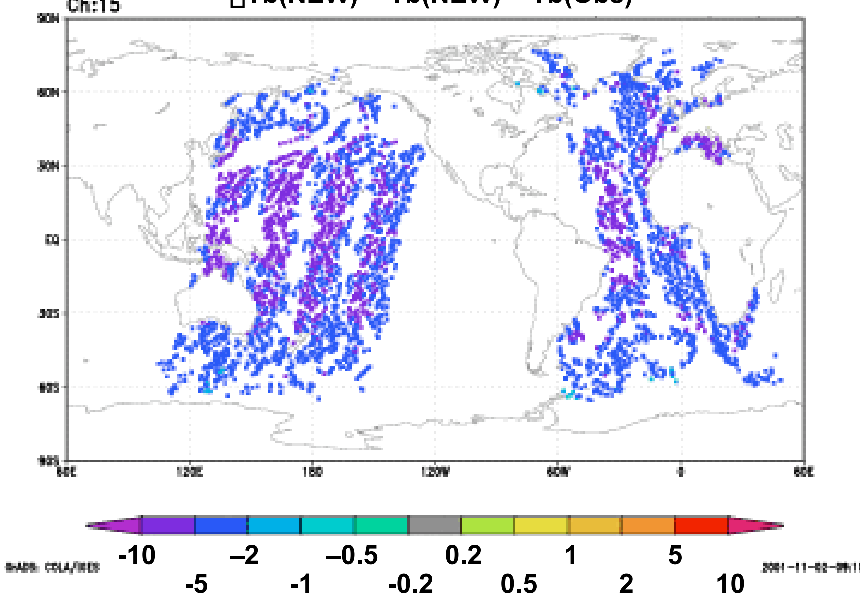


HIRS Ch.12 comparison, with bias correction

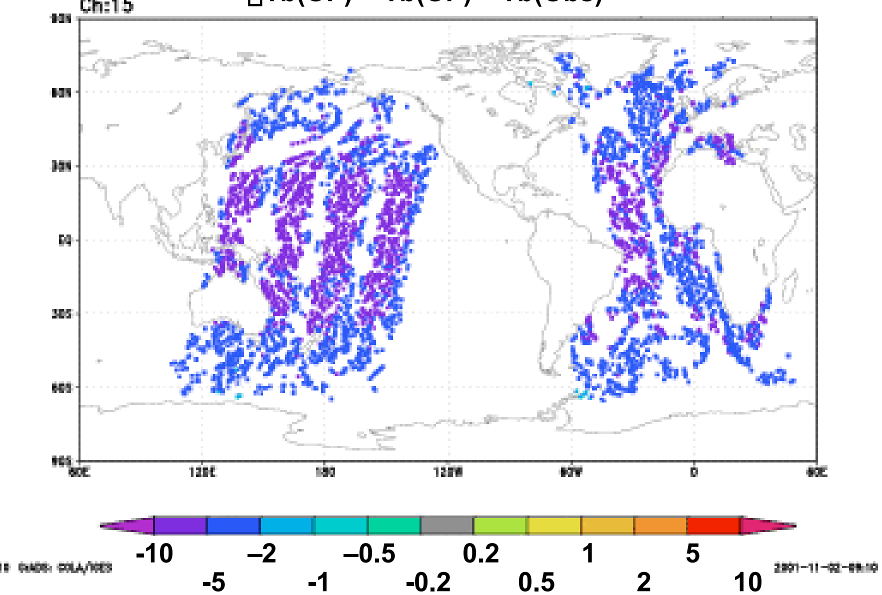


HIRS Ch.15 comparison, no bias correction

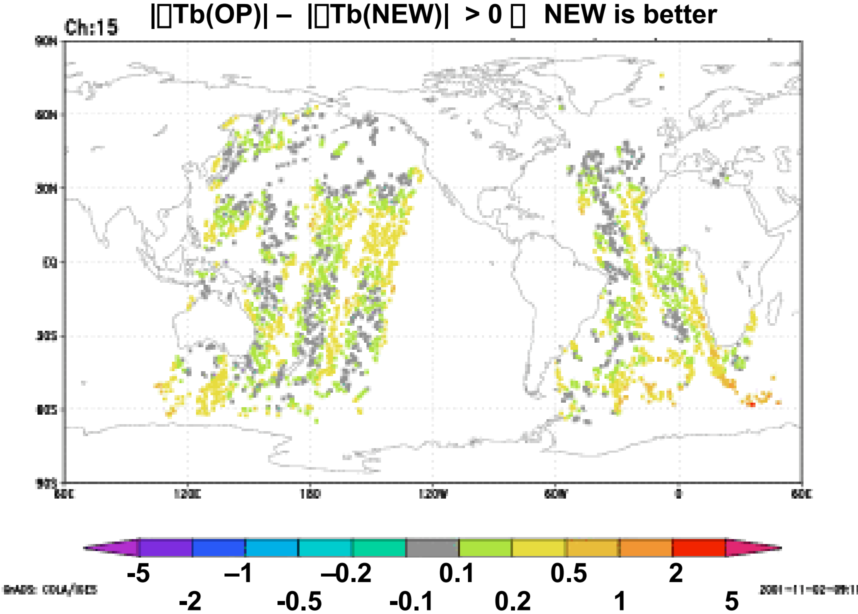
□Tb(NEW) = Tb(NEW) – Tb(Obs)



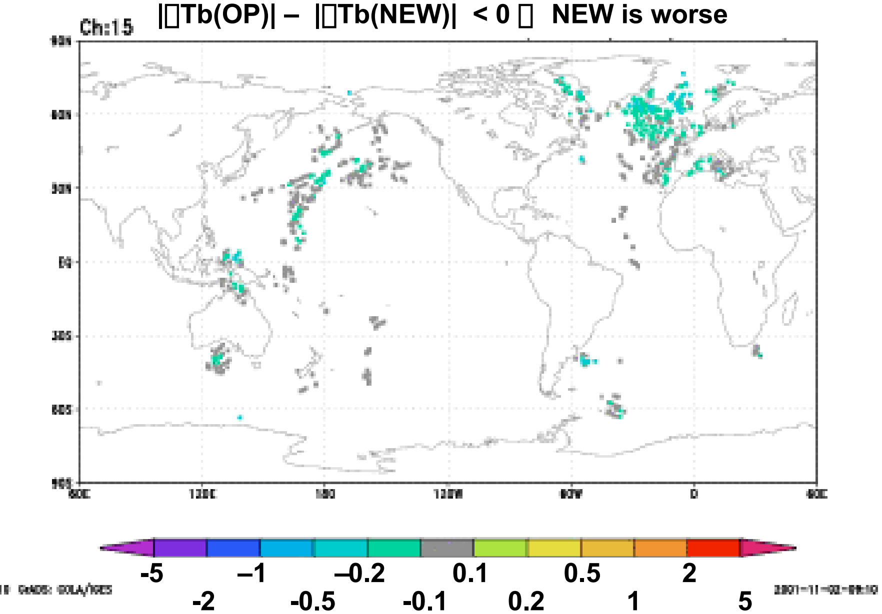
□Tb(OP) = Tb(OP) – Tb(Obs)



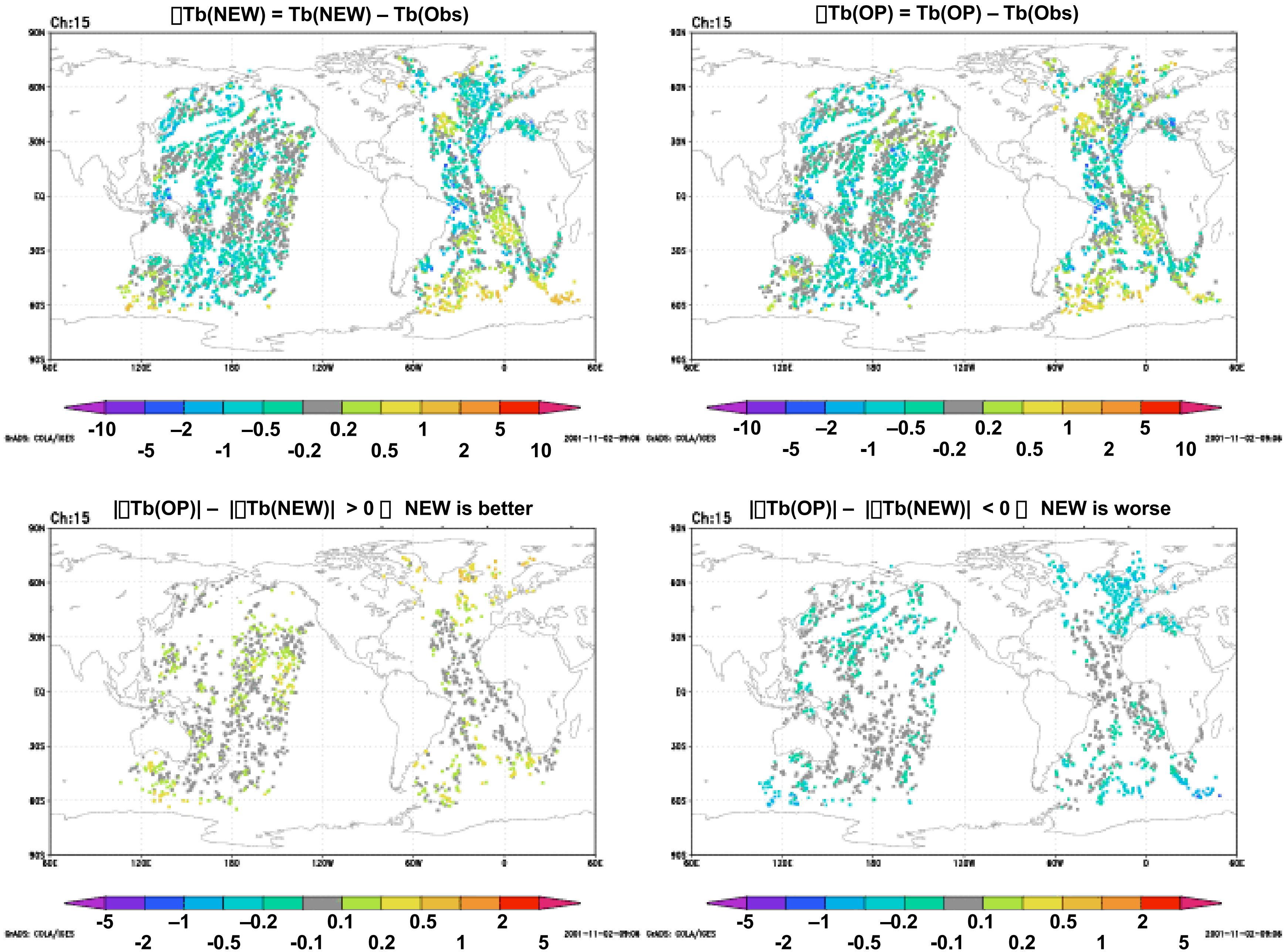
|□Tb(OP)| – |□Tb(NEW)| > 0 □ NEW is better



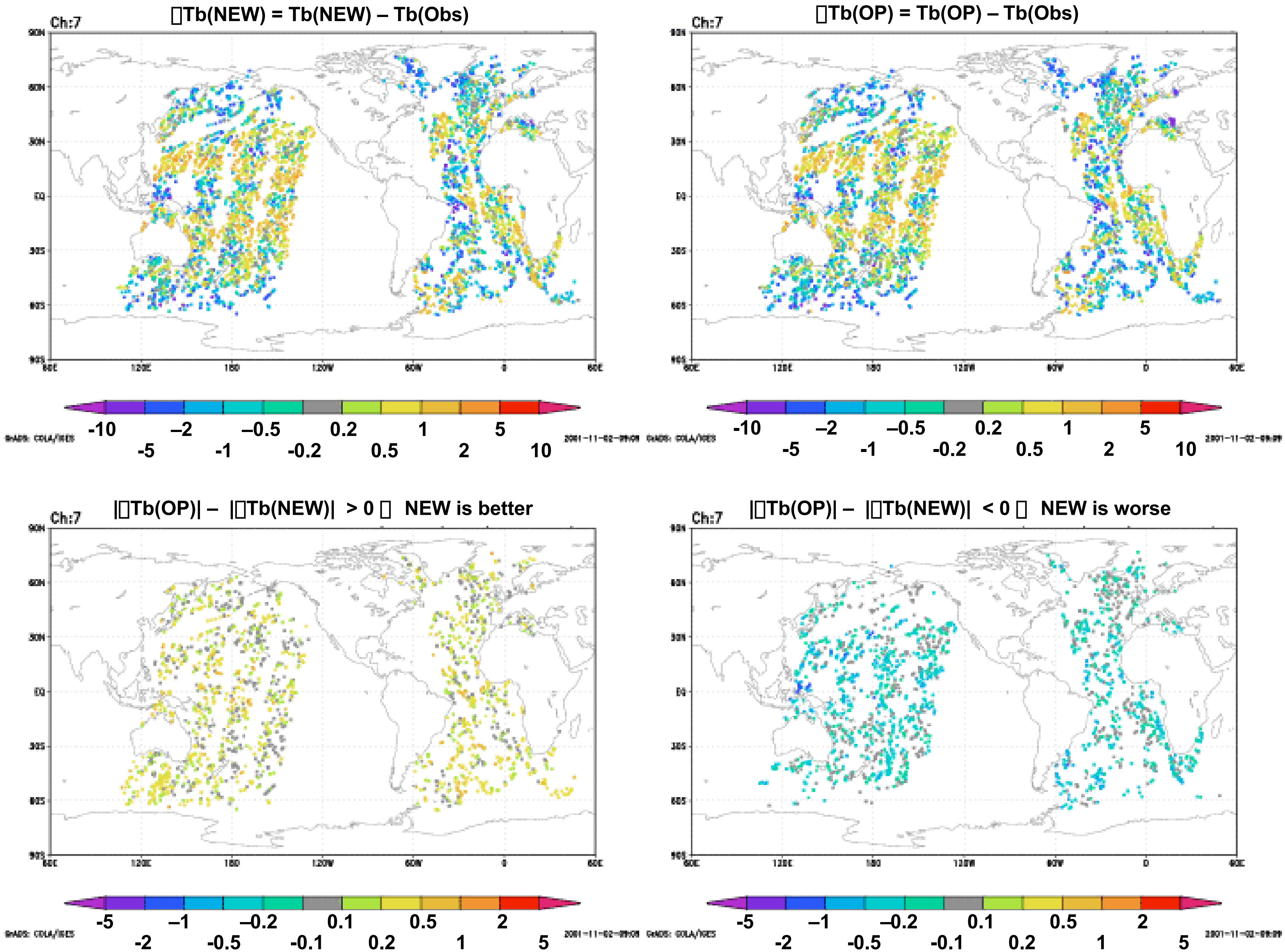
|□Tb(OP)| – |□Tb(NEW)| < 0 □ NEW is worse



HIRS Ch.15 comparison, with bias correction

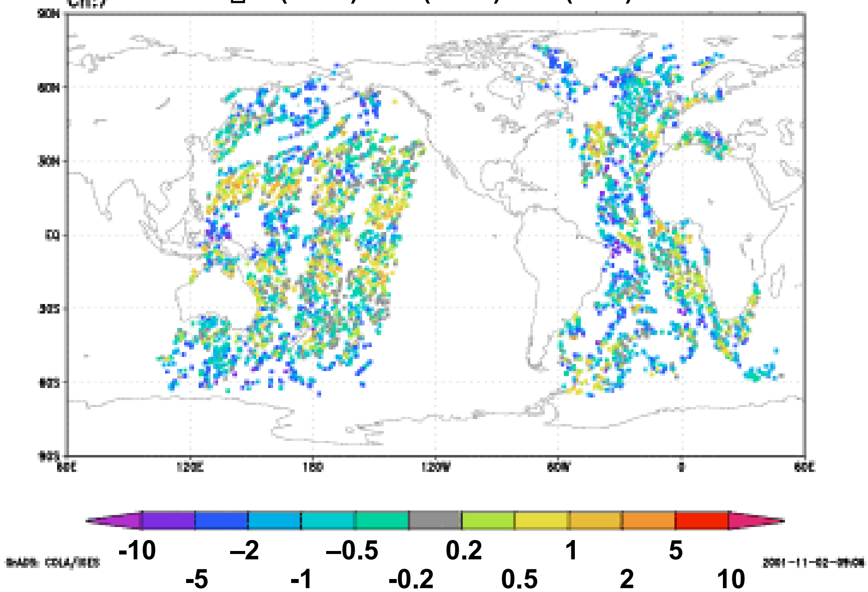


HIRS Ch.7 comparison, no bias correction

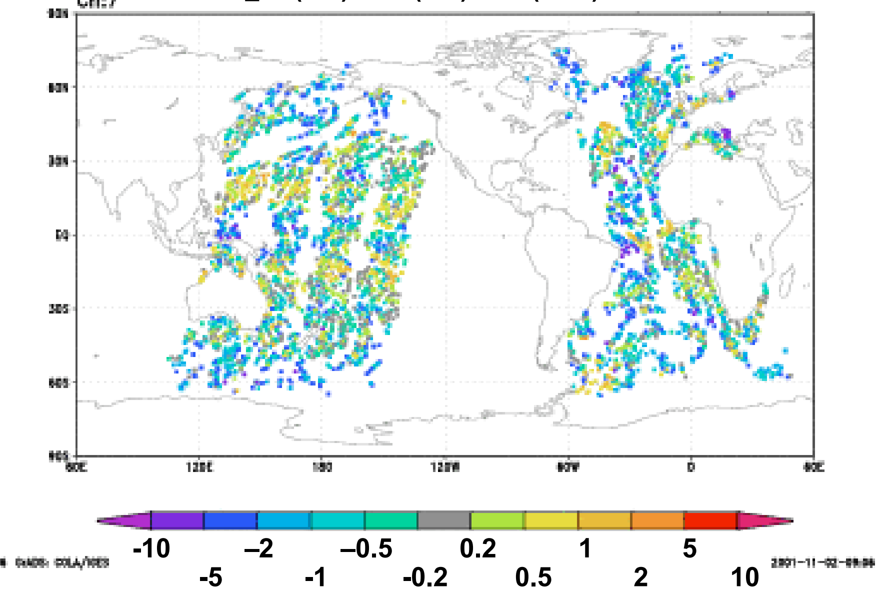


HIRS Ch.7 comparison, with bias correction

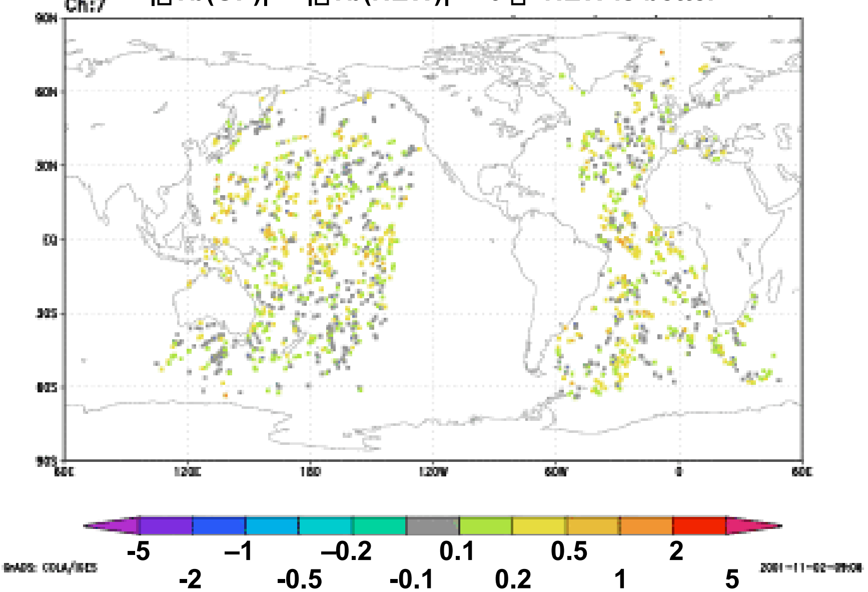
□Tb(NEW) = Tb(NEW) – Tb(Obs)



□Tb(OP) = Tb(OP) – Tb(Obs)



|□Tb(OP)| – |□Tb(NEW)| > 0 □ NEW is better



|□Tb(OP)| – |□Tb(NEW)| < 0 □ NEW is worse